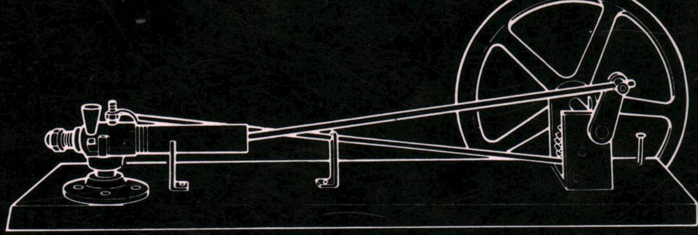
basic gasoline engine



Supplement to Select STST Courses

STST Service Technician Specialty Training

Ford Parts and Service Division
Technical Training

IMPORTANT SAFETY NOTICE

Appropriate service methods and proper repair procedures are essential for the safe, reliable operation of all motor vehicles, as well as the personal safety of the individual doing the work. This manual provides general directions for accomplishing service and repair work with tested, effective techniques. Following them will help assure reliability.

There are numerous variations in procedures, techniques, tools, and parts for servicing vehicles, as well as in the skill of the individual doing the work. This manual cannot possibly anticipate all such variations and provide advice or cautions as to each. Accordingly, anyone who departs from the instructions provided in this manual must first establish that he compromises neither his personal safety nor the vehicle integrity by his choice of methods, tools or parts.

As you read through the procedures, you will come across NOTES, CAUTIONS, AND WARNINGS. Each one is there for a specific purpose. NOTES give you added information that will help you to complete a particular procedure. CAUTIONS are given to prevent you from making an error that could damage the vehicle. WARNINGS remind you to be especially careful in those areas where carelessness can cause personal injury. The following list contains some general WARNINGS that you should follow when you work on a vehicle.

- Always wear safety glasses for eye protection.
- Use safety stands whenever a procedure requires you to be under the vehicle.
- Be sure that the ignition switch is always in the OFF position, unless otherwise required by the procedure.
- Set the parking brake when working on the vehicle. If you have an automatic transmission, set it in PARK unless instructed otherwise for a specific service operation. If you have a manual transmission, it should be in REVERSE (engine OFF) or NEUTRAL (engine ON) unless instructed otherwise for a specific service operation.
- Operate the engine only in a well-ventilated area to avoid the danger of carbon monoxide.
- Keep yourself and your clothing away from moving parts when the engine is running, especially the fan and belts.
- To prevent serious burns, avoid contact with hot metal parts such as the radiator, exhaust manifold, tail pipe, catalytic converter and muffler.
- Do not smoke while working on the vehicle.
- To avoid injury, always remove rings, watches, loose hanging jewelry, and loose clothing before beginning to work on a vehicle. Tie long hair securely behind the head.
- Keep hands and other objects clear of the radiator fan blades. Electric cooling fans start to operate at any time by an increase in underhood temperatures, even though the ignition is in the OFF position. Therefore, care should be taken to ensure that the electric cooling fan is completely disconnected when working under the hood.

The recommendations and suggestions contained in this manual are made to assist the dealer in improving his dealership parts and/or service department operations. These recommendations and suggestions do not supersede or override the provisions of the Warranty and Policy Manual, and in any cases where there may be a conflict, the provisions of the Warranty and Policy Manual shall govern.

The descriptions, testing procedures, and specifications in this handbook were in effect at the time the handbook was approved for printing. Ford Motor Company reserves the right to discontinue models at any time, or change specifications, design or testing procedures without notice and without incurring obligation. Any reference to brand names in this manual is intended merely as an example of the types of tools, lubricants, materials, etc. recommended for use. Equivalents if available may be used. The right is reserved to make changes at any time without notice.

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BASIC GASOLINE ENGINE

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BASIC GASOLINE ENGINE

INTRODUCTION TO THE FOUR STROKE GASOLINE ENGINE

This Certified Training Program is intended to supply the technician with a basic understanding of the principles of operation of the four stroke gasoline engine. It is not a "What's New," "How To," or "What For" type of program. It is intended to provide a basic knowledge adaptable to changes in automotive technology.

A technician that is just beginning a career, or a technician with years of experience must understand the basic operation of the engine in order to gain the ability to "keep up."

As emission controls and mileage requirements complicate the gasoline engine, a technician's time must be spent studying and understanding these rapid changes. Anyone can study, understanding requires a good basic knowledge of the subject. It is the purpose of this training manual to present the basic principles of the four stroke gasoline engine in simplified format.

There are many variations of the gasoline engine. For this reason the manual will not provide specific examples of each. Rather, the basic principles upon which all four stroke cycle engines operate will be presented.

OBJECTIVES

Technicians who carefully study "Basic Principles of the Four Stroke Gasoline Engine," can expect the following advantages in automotive servicing:

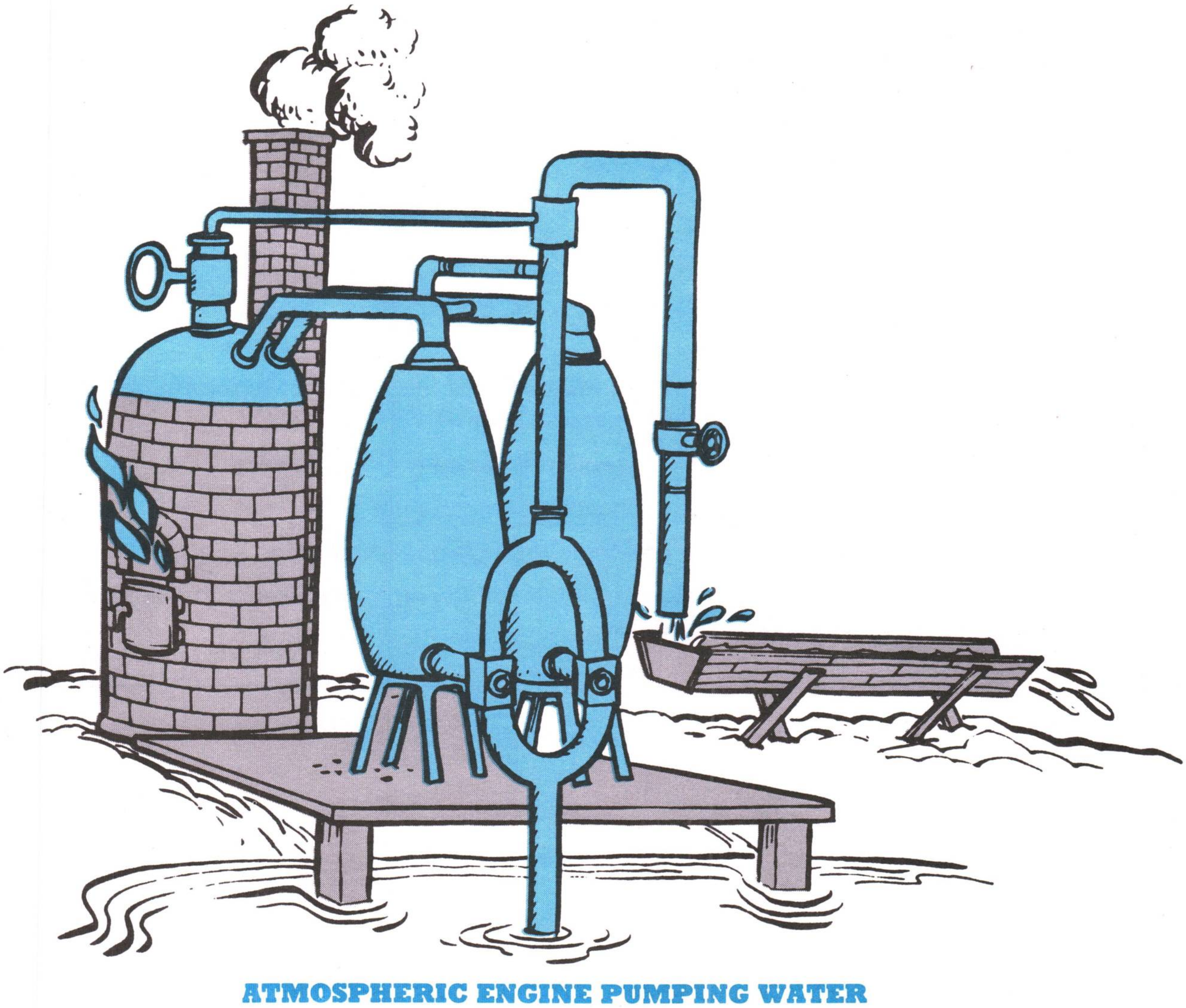
- The ability to understand how a gasoline engine develops power.
- The operation and purpose of each of its components.
- The ability to better diagnose problems through understanding.
- The basic knowledge of the four stroke gasoline engine necessary to "keep up" with changes in its design and operation.

A BRIEF HISTORY OF THE INTERNAL COMBUSTION ENGINE

The development of the internal combustion engine was made possible by the earlier development of the atmospheric engine and the steam engine. All three engines burn fuel, releasing energy from it in the form of heat, which is then used to do work.

The atmospheric engine is the earliest type of steam engine. The first demonstration of the principle of the atmospheric engine took place in 1690. The demonstration was conducted by Denis Papin, the inventor of the pressure cooker.

An atmospheric engine works by admitting steam into a container and then cooling it with cold water. This causes the steam to condense back to water, greatly reducing its volume, and forming a partial vacuum in the container. The pressure difference between the vacuum in the container and the outside air is then used to do work. The amount of work this type of engine can perform is limited. All of the early atmospheric engines were used to pump water.

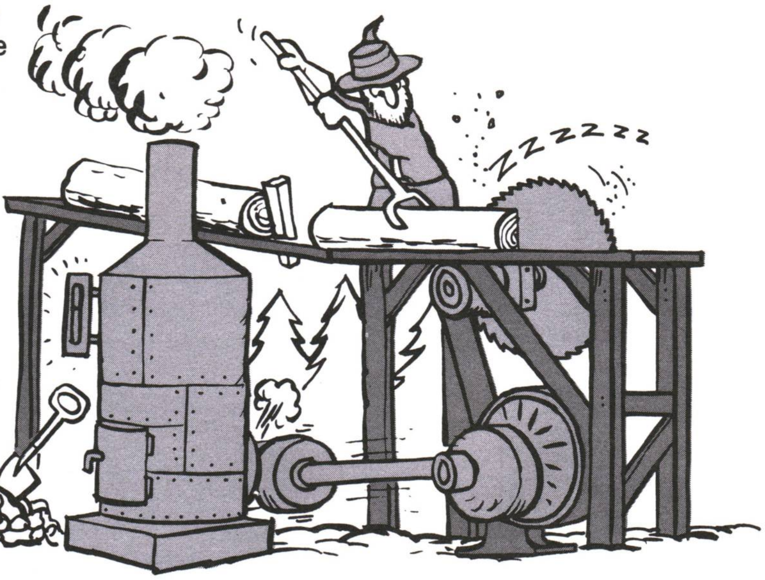


ATMOSPHERIC ENGINE PUMPING WATER

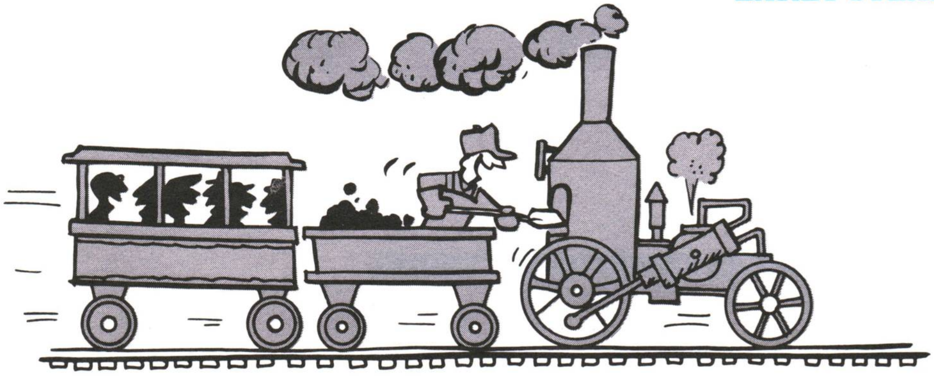
BASIC GASOLINE ENGINE

The principles of the atmospheric engine led to the development of the basic steam engine. The basic steam engine was developed in the last quarter of the 18th century by James Watt and Richard Trevithick.

The steam engine, like the atmospheric engine, is an external combustion engine, that is, the fuel is burned outside the working cylinder.



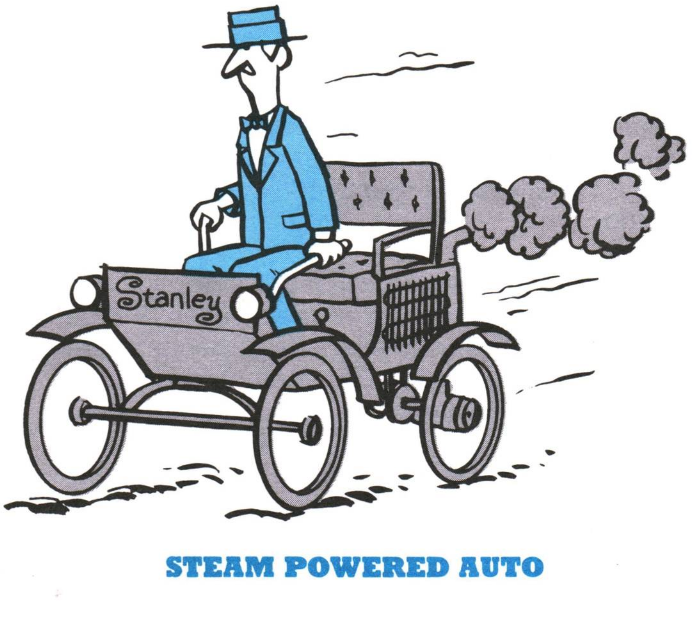
EARLY STEAM ENGINE SAW MILL



STEAM POWERED TRAIN

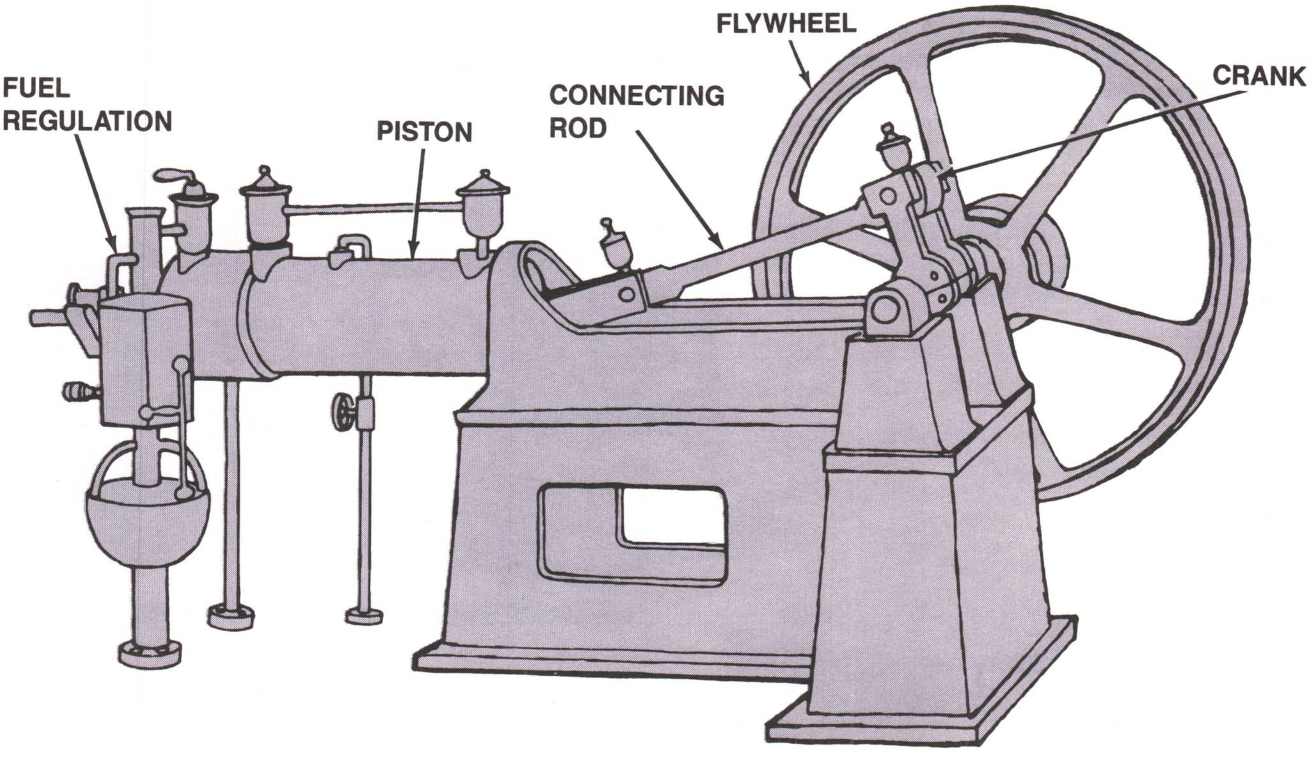
The fuel burning does not take place in the cylinder, it takes place in a separate part of the engine. Anything combustible can be used to fuel a steam engine. The most common fuels being wood, coal or petroleum products. The liberated energy caused by burning these fuels is used to heat a liquid, usually water. The hot water vapor expands into a confined place, the cylinder, and is used to push the piston.

The steam engine dominated industry and transport for 150 years. In the early days of the automobile Stanley marketed a steam power automobile which sold over 60,000 units. Steam for automobiles was not practical as the unit needed fuel for the boiler and water for steam to produce power. In time the steam engine in automobiles was replaced entirely by the internal combustion engine.



STEAM POWERED AUTO

BASIC GASOLINE ENGINE



EARLY INTERNAL COMBUSTION ENGINE

In the internal combustion engine, the burning of fuel takes place in the combustion chamber. The combustion is sudden, almost an explosion, which pushes the piston down.

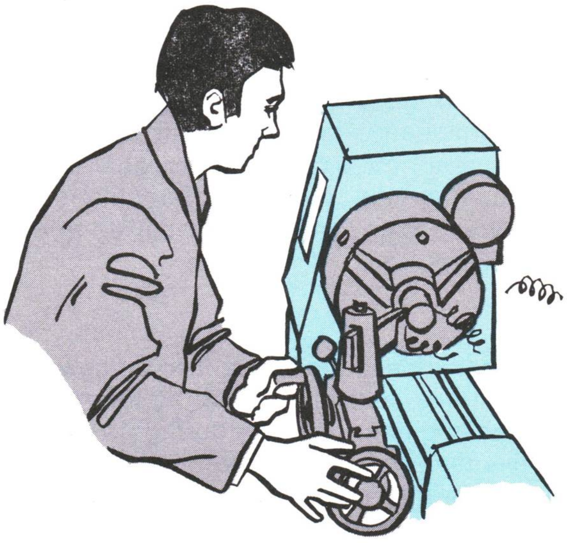
During the eighteenth and nineteenth centuries advancements were made in engineering and metallurgy. These advancements made possible the first successful internal combustion engines.

In 1824 a French physicist, Sadi Carnot, published his theories which led to the science of heat exchange thermodynamics. These theories aided development of the steam engine and added greatly to the development of the internal combustion engine. Fifty years before these theories were published James Watt had already begun to develop piston rings and packings which would prevent energy from escaping past the piston in his steam engines.

In the 1850's more volatile fuels were being refined from petroleum. This was another necessary step in producing the internal combustion engine.

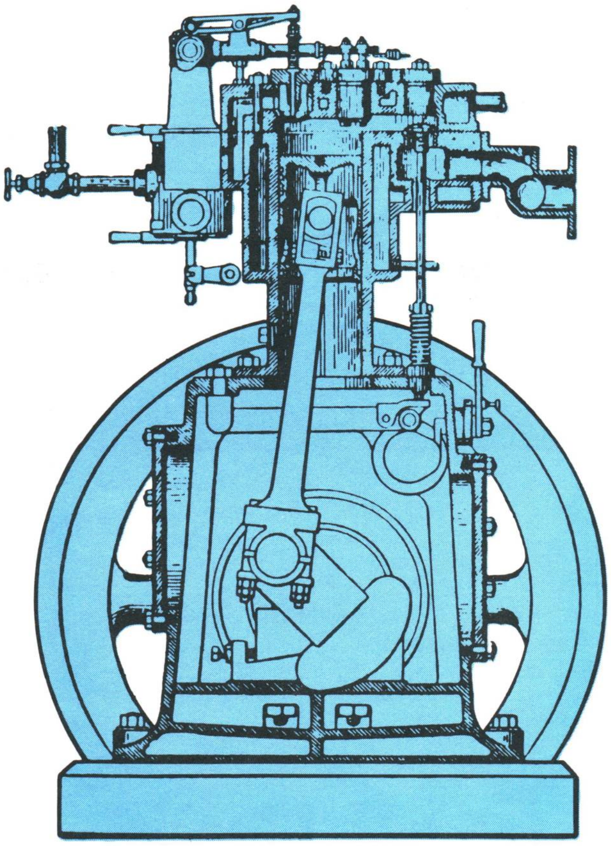
BASIC GASOLINE ENGINE

By 1800 a British engineer, Henry Maudslay, was making improvements to the lathe. This led to machinery capable of producing precision-made parts for engines.



During 1860 J.J.E. Lenoir, a French engineer, built a successful engine, which was essentially a modified steam engine. The engine used illuminating gas as the fuel.

Alphonse Beau DeRochas, in 1862, published his theory of a four-stroke engine. DeRochas never built an engine but his theory did include compression of the fuel mixture in order to raise its temperature. He also realized that a four stroke design would be more efficient at scavenging (intake of fuel mixture and exhausting of burned gases) than the two stroke design.



The firm of Otto and Langen began producing an engine in 1867 that transmitted the power of a free moving piston to a shaft and heavy flywheel by means of a rack and gear device. The unit used a free wheeling clutch in the gear, so as to turn freely in one direction and transmit power in the other.

In 1876, Otto and Langen begain building what they called the "Otto Silent Engine." This engine was said to be a good deal quieter than their earlier model. This was the first modern internal combustion engine. It was a four stroke cycle design, which compressed the air fuel mixture before combustion. This engine was produced in the United States after 1878 and served as an inspiration to Henry Ford in his early research.

Henry Ford's interest in the internal combustion engine began long before it was fashionable. He began experiments with internal combustion engines around 1890 and at one point built a working engine in his wife's kitchen.

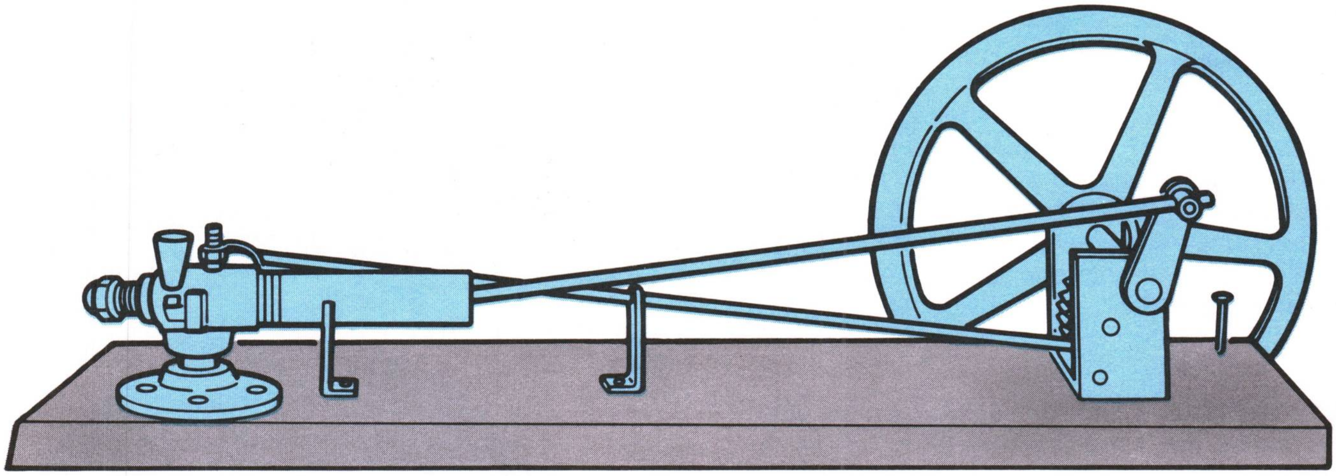
BASIC GASOLINE ENGINE

Henry Ford continued experiments and development of internal combustion engines until his death in 1947. He held many patents on the production and manufacturing of internal combustion engines and components. In 1935 he received a patent for a four cylinder, gear driven, overhead cam engine. This type of engine is highly regarded today, yet was conceived in the 1930's by Henry Ford.

Although many ideas are thought to be new, most design and development of the internal combustion engine took place during its early years. Advancements in materials and machining have made many old ideas practical and usable in today's modern engines.

Gasoline engines found in today's automobiles are generally of the four stroke cycle design, commonly called four cycle engines. They are internal combustion spark ignition engines. Internal combustion engines are heat engines, delivering power by momentary combustion of fuel in one or more working cylinders. Ignition of the compressed fuel mixture is controlled by a timed external ignition source.

The four stroke cycle engine derives its name from the up and down action of a piston during one complete cycle. To complete one cycle of the four stroke cycle engine, the piston travels the length of its stroke (up and down).



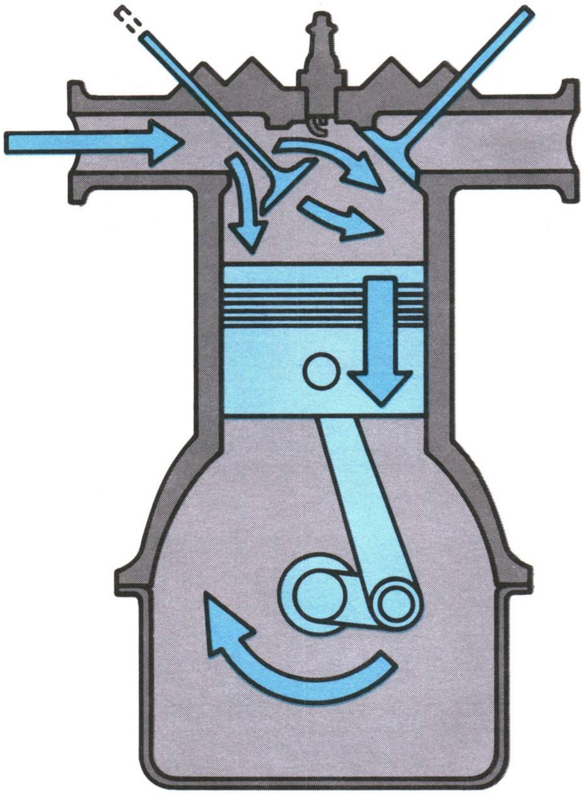
FORD'S SINK ENGINE

PRINCIPLES OF THE FOUR STROKE CYCLE THEORY

INTAKE STROKE

As the piston moves away from T.D.C. (top dead center), the intake valve opens. The downward movement of the piston increases the volume of the cylinder above it. This in turn reduces the pressure in the cylinder below atmospheric pressure. The reduced pressure causes atmospheric pressure to push a mixture of air and fuel through the open intake valve. As the piston reaches the bottom of its stroke, the reduction in pressure stops and the intake of fuel nearly ceases. But due to the weight and movement of the air fuel mixture, it will continue to enter the cylinder until the intake valve closes. The delayed closing of the intake valve increases the volumetric efficiency of the cylinder by packing as much air and fuel into it as possible.

Volumetric efficiency of any four stroke cycle gasoline engine is the difference between how much air and fuel will enter the cylinder with the engine running, compared to the total volume of the cylinder which is determined by its bore and stroke.



"INTAKE"

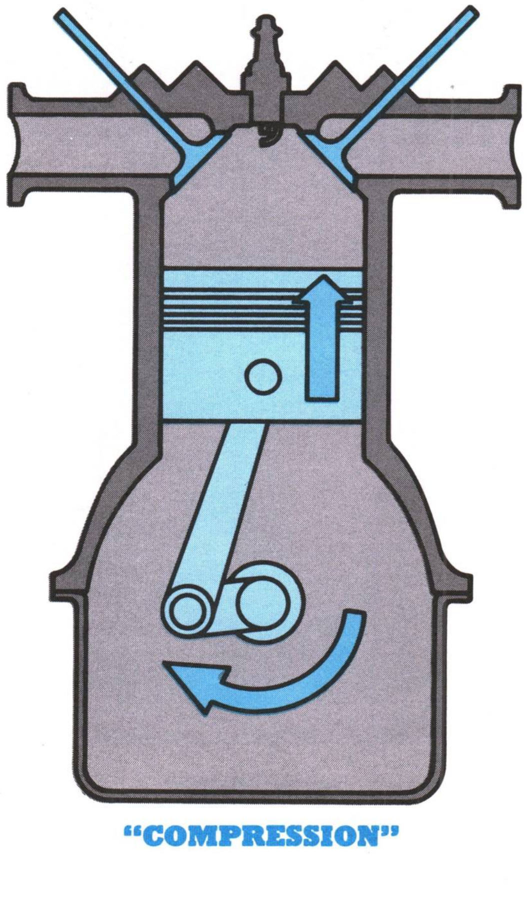
COMPRESSION STROKE

The compression stroke begins as the piston starts to move from B.D.C. (bottom dead center). The intake valve closes, trapping the air fuel mixture in the cylinder. Upward movement of the piston compresses the air fuel mixture. At T.D.C. the piston and cylinder walls form a combustion chamber in which the fuel will be burned. The volume of the cylinder, with the piston at T.D.C. compared to the volume of the cylinder with the piston at B.D.C. determines the compression ratio of the engine.

The compression ratio of an engine is the volume in one cylinder with the piston at bottom dead center, (big V) plus the volume of the cylinder with the piston at top dead center, (small V) divided by the volume of the cylinder with the piston at top dead center (small V). This figure indicates the actual amount that the air drawn into the cylinder will be compressed. For example, suppose that an engine cylinder has a volume of 575cc with the piston at B.D.C. and a volume of 75cc with the piston at T.D.C. This gives a compression ratio of 575 plus 75 divided by 75 or 8.6:1. That is, the air is compressed from 650cc to 75cc, or to 1/8.6 of its original volume, on the compression stroke.

To determine the compression ratio of a given engine you must know two specifications. First, you must know the cylinder swept volume. This is the total volume of the cylinder and combustion chamber with the piston at B.D.C. This we will call Big V. Second, you must know the volume of the combustion chamber. This is the volume of the cylinder and combustion chamber with the piston at T.D.C. We will call this small V. When we know these two volumes, a simple formula to find compression ratio would be, Big V plus small V, divided by small V equals compression ratio.

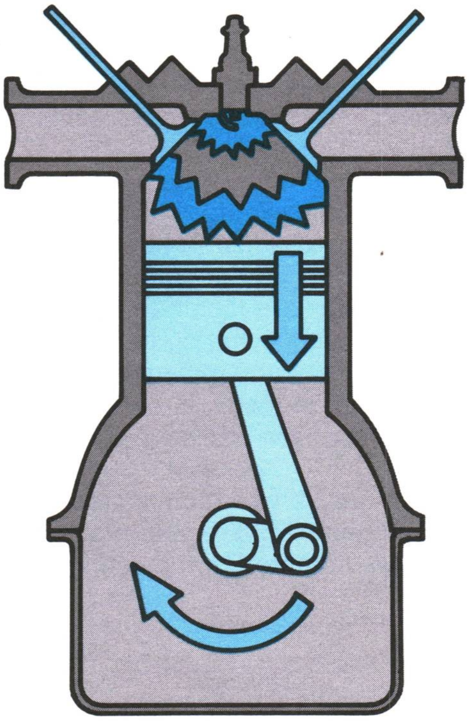
$$\frac{\text{Big V} + \text{Small V}}{\text{Small V}} = \text{Compression Ratio}$$



“COMPRESSION”

BASIC GASOLINE ENGINE

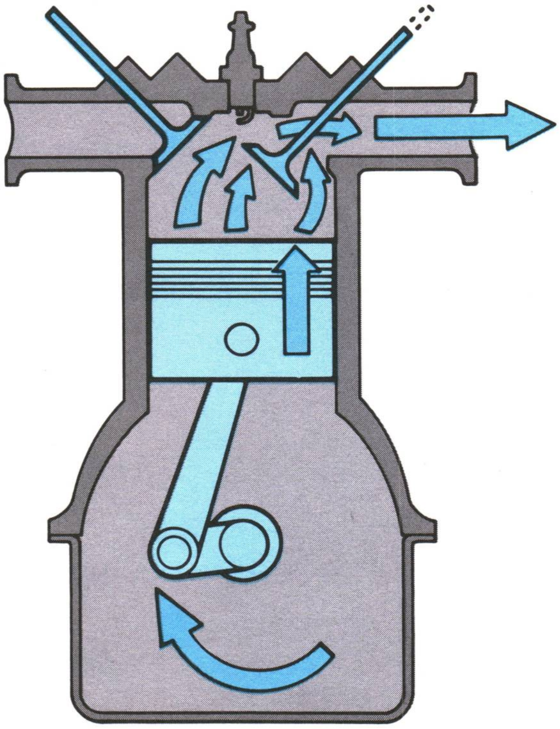
POWER STROKE



"POWER"

The power stroke begins as the compressed fuel mixture is ignited in the combustion chamber. An electrical spark across the electrode of a spark plug ignites the air fuel mixture. The burning fuel rapidly expands creating a very high pressure against the top of the piston. This drives the piston down toward B.D.C. The downward movement of the piston is transmitted through the connecting rod to the crankshaft. Up and down movement of the piston on all four strokes is converted to rotary motion of the crankshaft.

EXHAUST STROKE



"EXHAUST"

The exhaust valve opens just prior to the piston reaching B.D.C. on the power stroke. Pressure within the cylinder when the valve opens causes the exhaust gases to rush past the valve and into the exhaust system. Movement of the piston from B.D.C. pushes most of the remaining exhaust gas from the cylinder. As the piston nears T.D.C. the exhaust valve begins to close as the intake valve starts to open. Both valves will be opened momentarily. This condition is called valve overlap. During valve overlap, incoming air and fuel will continue to purge the cylinder until the exhaust valve closes.

The exhaust stroke completes the four stroke cycle, the opening of the intake valve begins the cycle again. This cycle is occuring in each cylinder and will be repeated over and over, as long as the engine is running.

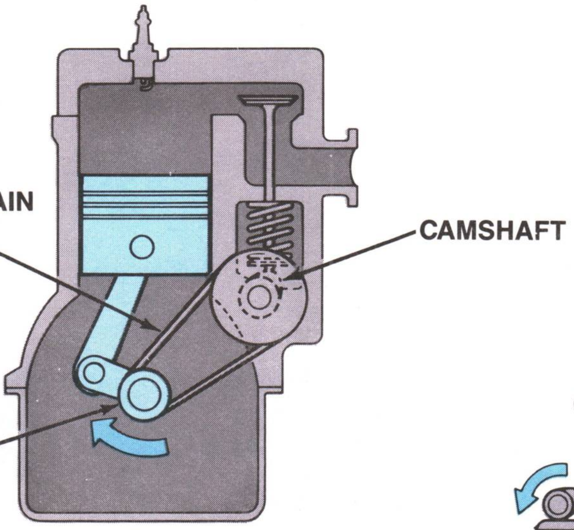
BASIC GASOLINE ENGINE

There are three basic valve and camshaft placement configurations, of the four stroke gasoline engines, used in automobiles. They are the flat head, overhead valve and overhead camshaft.

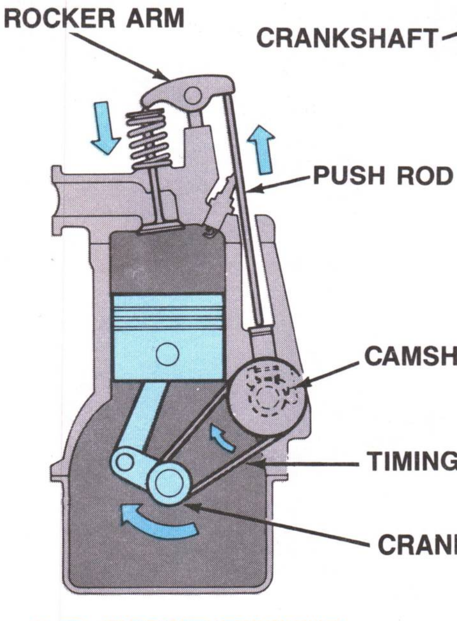
First, the flat head engine. This engine is also know as the "L" head or side valve engine. No moving parts are contained in the cylinder head. The head serves only as the combustion chamber. The valves are located in the cylinder block along side each cylinder, hence the name side valve. The intake and exhaust manifolds mount to the cylinder block. In automobiles this type of engine has been lost to progress.

Next, the overhead valve which is also known as "OHV." As the name implies the intake and exhaust valves are mounted in the cylinder head and are operated by a camshaft located in the cylinder block. This arrangement requires the use of valve lifters, push rods and rocker arms to transfer camshaft rotation to valve movement. The intake and exhaust manifolds are attached to the cylinder head.

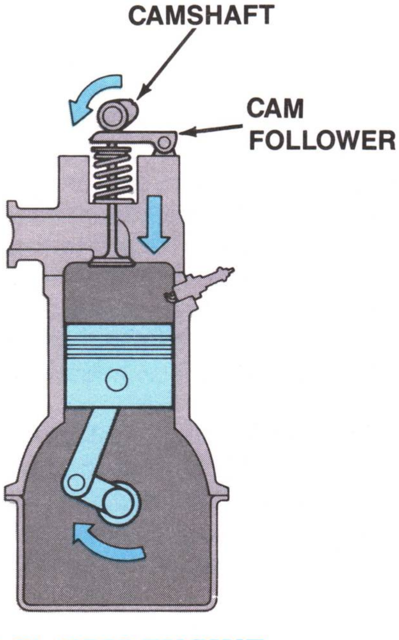
Overhead cam engines also have the intake and exhaust valves located in the cylinder head; but as the name implies, the cam has now been relocated to the cylinder head as well. In an overhead cam engine the valves are operated directly by the camshaft and cam follower.



FLAT HEAD OR SIDE VALVE ENGINE



O.H. VALVE ENGINE

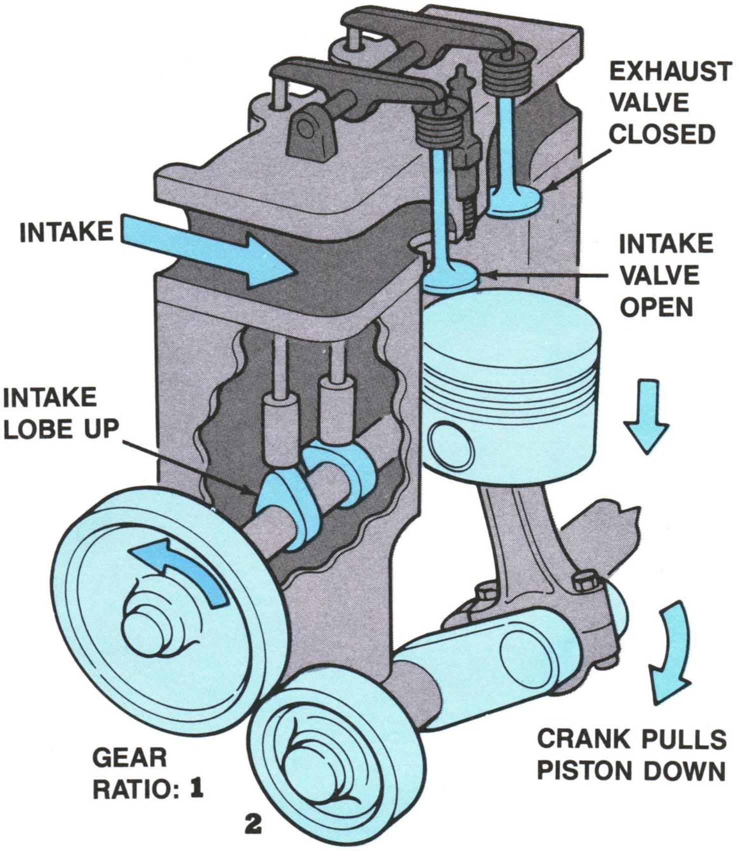


O.H. CAM ENGINE

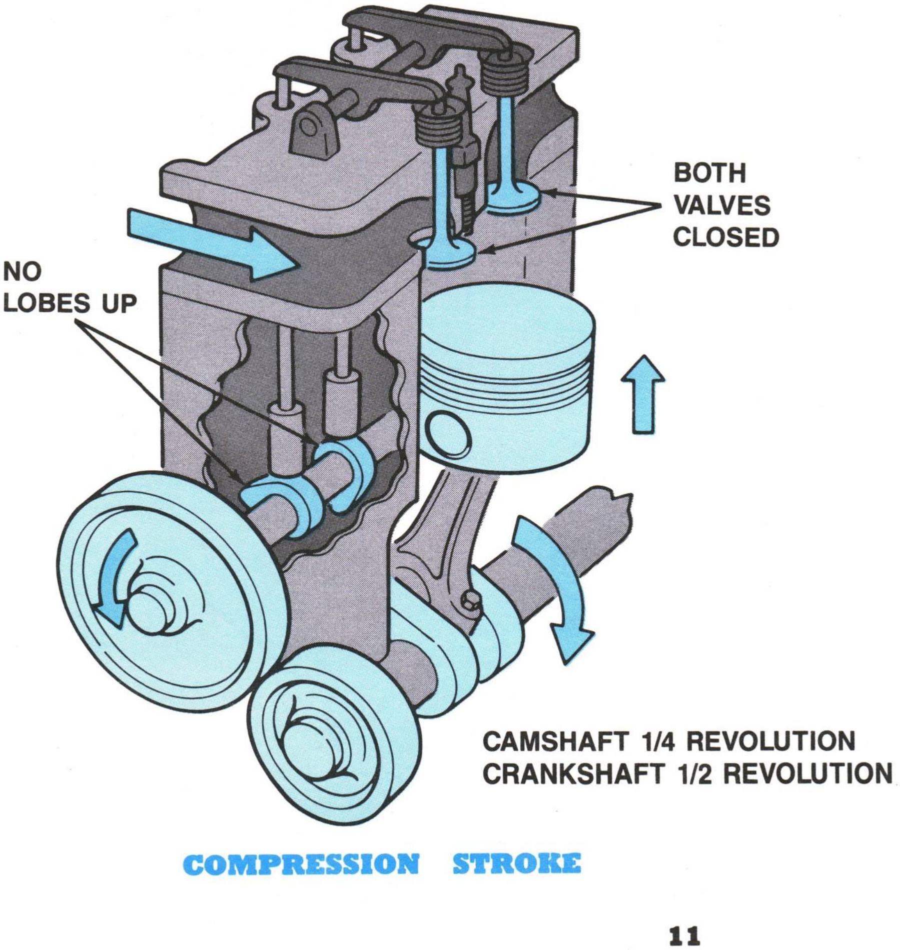
BASIC GASOLINE ENGINE

VALVE OPERATION

In overhead valve engines, the valves are operated by valve lifters and push rods which are actuated by the camshaft. On overhead cam engines, the cam lobes operate the valves directly and there is no need for push rods or lifters. The cam lobes are oval shaped. The placement of the lobe determines when the valve will open. Design of the lobe determines how wide the valve will open and how long it will remain open in relation to piston movement.



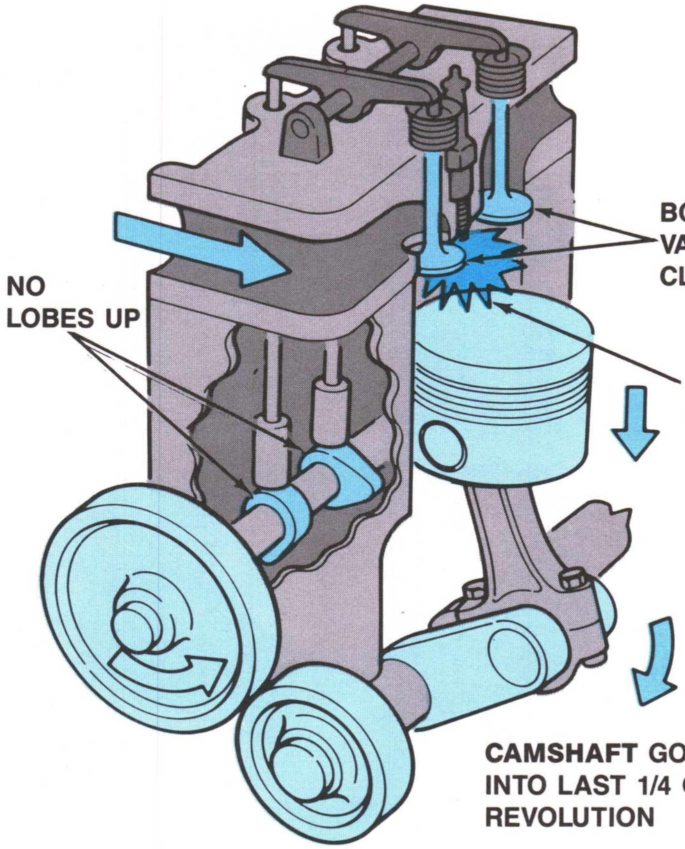
INTAKE STROKE



COMPRESSION STROKE

BASIC GASOLINE ENGINE

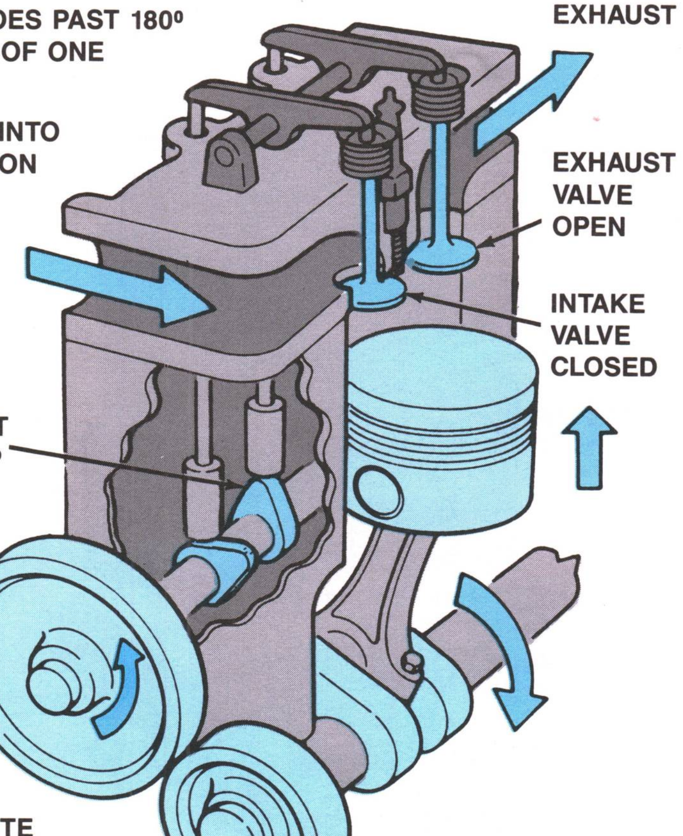
The camshaft is driven by the crankshaft through gears, or gears and a cogged belt, or timing chain. The camshaft turns at one half of the crankshaft speed and rotates one complete turn during each complete four stroke cycle.



CAMSHAFT GOES PAST 180°
INTO LAST 1/4 OF ONE
REVOLUTION

CRANK GOES INTO
2ND REVOLUTION

POWER STROKE



CAMSHAFT:
FINISHING **ONE** COMPLETE
REVOLUTION

CRANKSHAFT:
COMPLETING **TWO** REVOLUTIONS

EXHAUST STROKE

COMPONENTS OF THE FOUR STROKE GASOLINE ENGINE

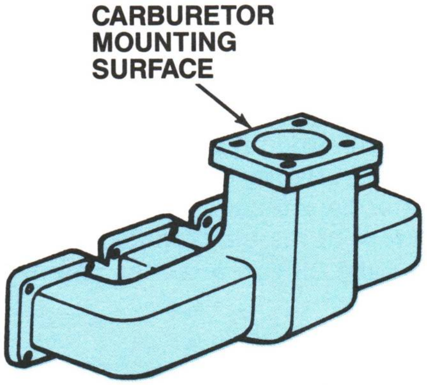
Gasoline engines as we know them are made up of many different parts and components. In this section we will review the components of the engine itself. Accessories will be covered in later sections of this manual.

INTAKE MANIFOLD

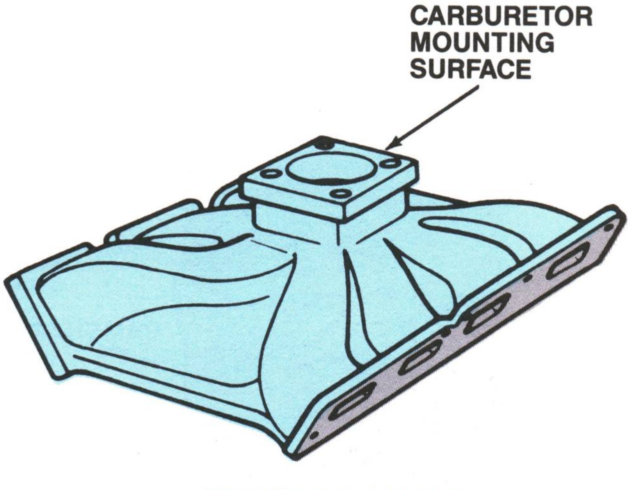
The intake manifold is the mounting point for the carburetor or fuel injection components.

The intake manifold distributes fuel as evenly as possible to each cylinder, helps to prevent condensation, and assists in vaporization of the air fuel mixture. Smooth and efficient engine performance depends on mixtures entering each cylinder that are uniform in strength, quality and degree of vaporization. This is partly the job of the intake manifold. The ideal air fuel mixture is completely vaporized when it goes into the combustion chamber. Complete vaporization requires high temperature and high temperature increases volume and decreases the volumetric efficiency of the engine. Therefore, the best alternative is to introduce an air fuel mixture into the manifold that is vaporized above the point where fuel particles will be deposited on the manifold and below the point where excess heat results in power losses. Intake manifolds are carefully designed to meet these requirements. The walls of the manifold must be smooth and offer no obstruction to the flow of the air fuel mixture. Design must also prevent collecting of fuel at the bends in the manifold.

The intake manifold should be as short and straight as possible to reduce the chances of fuel condensation between the carburetor and cylinders. To assist in vaporization of the fuel some intake manifolds are heated by exhaust or engine coolant. This helps to vaporize the fuel, a particularly important action in cold conditions when fuel vaporization is slow.



TYPICAL 4 CYL.-6 CYL. INLINE INTAKE MANIFOLD



TYPICAL V-6 & V-8 INTAKE MANIFOLD

BASIC GASOLINE ENGINE

CYLINDER BLOCK

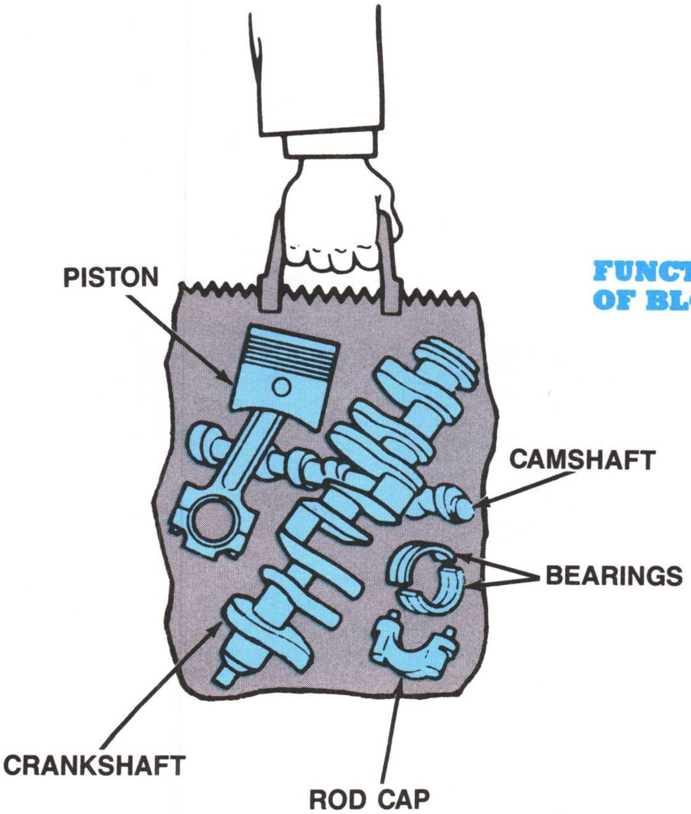
Since the cylinder block serves as the container for most of the engine components, we will begin with it.

The cylinder block is normally one piece, cast and machined so that all the parts contained in it fit properly. The word cast, with regard to the engine block, refers to how it is made. To cast is to form molten metal into a particular shape by pouring or pressing it into a mold. This molded piece must then undergo a number of machining operations to make sure all the working surfaces are smooth and true. The top of the block must be perfectly smooth as the cylinder head will later be attached at this point. The base or bottom of the block must also be machined as the oil pan attaches here. All block sealing areas are also machined. The cylinder bores must be smooth and a proper diameter to accept the pistons.

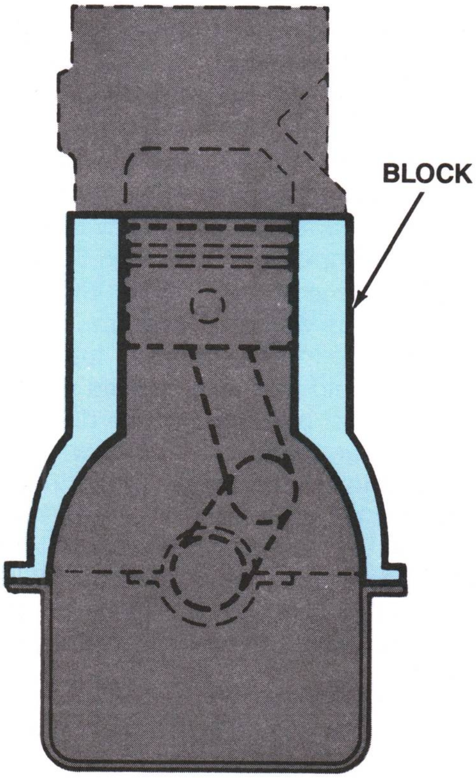
The main bearing area of the block must be line bored to a diameter which will accept the crankshaft. Camshaft bearing surfaces must also be bored. The word bore means to drill or machine a hole, line boring is a series of holes in a straight line.

Cylinder blocks are cast from several different materials, some are cast iron, some cast aluminum. Today, even plastic is being tested as a material for block construction. The benefits of each will be covered later in this manual.

THE BLOCK



FUNCTION OF BLOCK



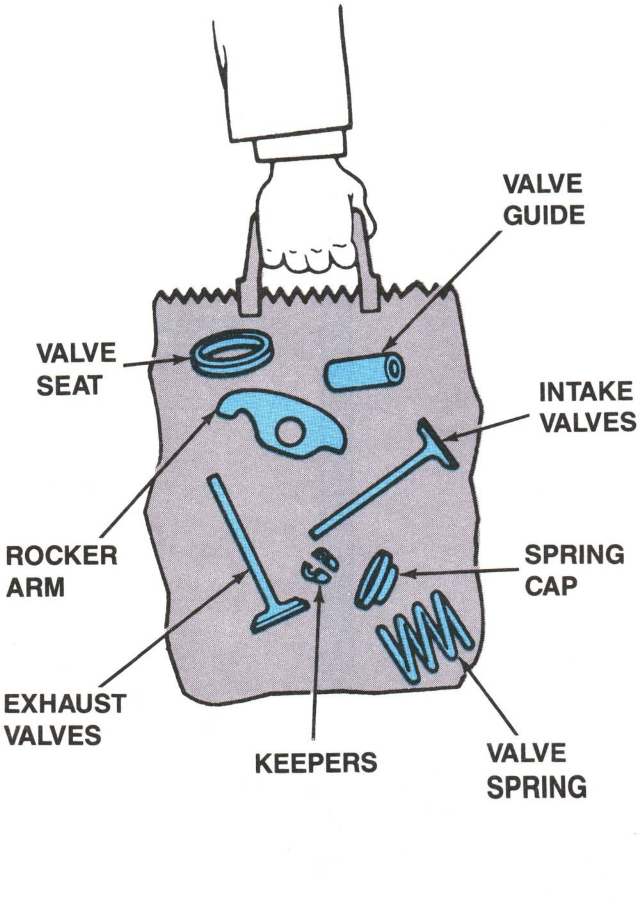
BASIC GASOLINE ENGINE

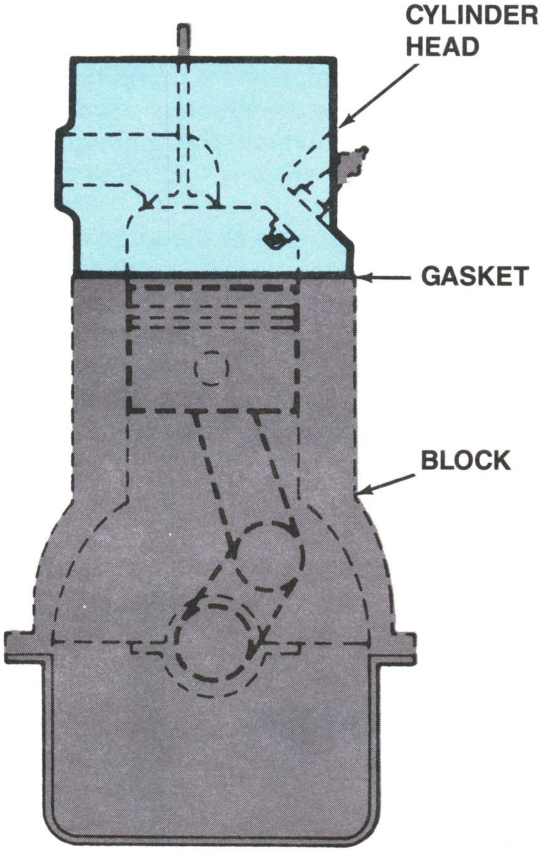
CYLINDER HEAD

The cylinder head is normally made of cast iron or aluminum. It contains, on overhead valve engines, the valves, valve seats, valve guides, valve springs, rocker arm supports and a recessed area called the combustion chamber. In overhead camshaft engines you will also find the supports for the camshaft and the camshaft bearings. Both types of cylinder heads contain passages which match passages in the cylinder block to allow coolant to circulate in the head. The cylinder head also contains tapped holes in the combustion chamber to accept the spark plugs.

The surface of the head which contacts the block must be perfectly smooth as this area must contain the force of the burning fuel mixture. To aid in the sealing, a gasket is placed between the head and block. This gasket is called the head gasket. The gasket is made of special material which can withstand high temperatures, high pressures and the expansion of the metals around it. The head also serves as the mounting point for the intake and exhaust manifolds and contains the intake and exhaust ports.

THE HEAD





FUNCTION OF HEAD

INTAKE AND EXHAUST VALVES

Every cylinder of a four stroke cycle engine contains at least one intake valve to permit the air fuel mixture to enter the cylinder, and one exhaust valve to allow the burned exhaust gases to escape. The intake and exhaust valves, along with the cylinder head gasket, must also seal the combustion chamber.

The type of valve used in automotive engines is called a poppet. The word "poppet" is derived from the popping action of the valve as it opens and closes.

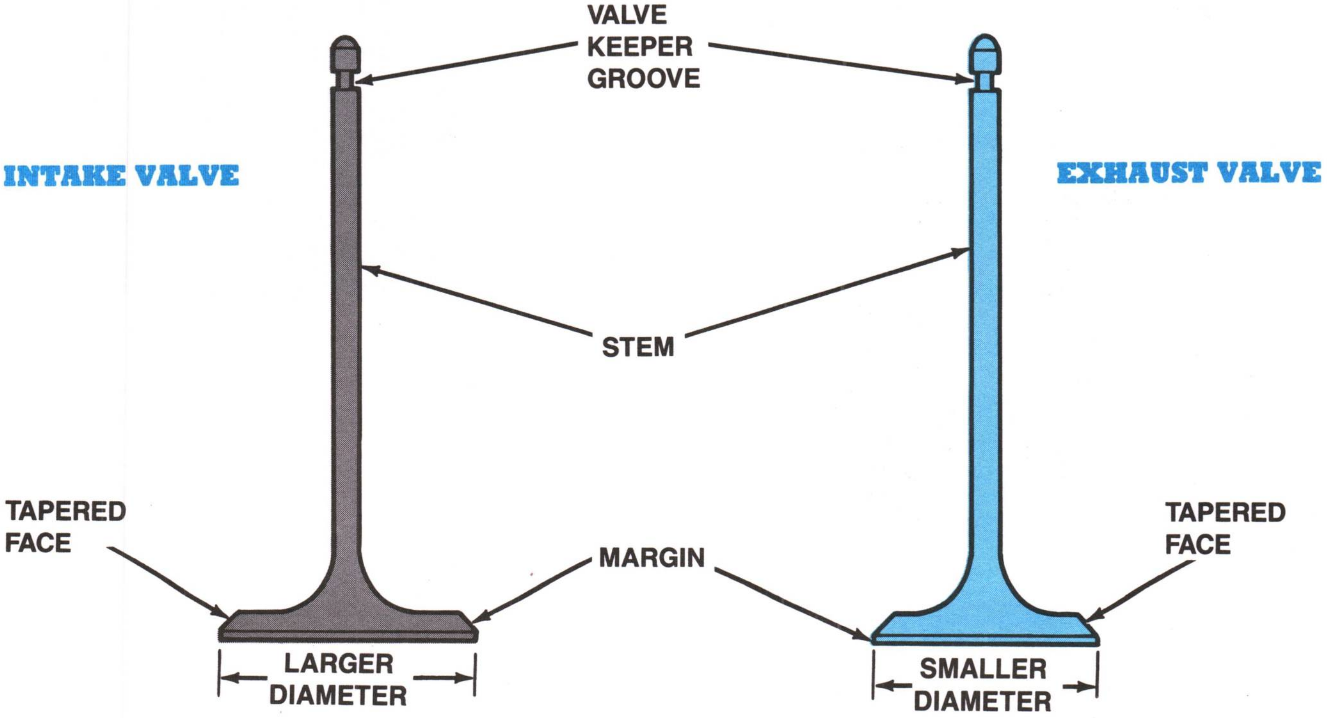
A poppet type valve has a round head with a tapered face, a stem which is used to guide the valve, and a slot which is machined at the top of the stem for the valve spring retainers.

The head of the valve is the large diameter end and is used to seal the intake or exhaust port. This seal is made by the valve face contacting the valve seat. The valve face is the tapered area machined on the head of the valve. The angle of this taper is determined by design and manufacture of the engine. The taper will vary from one engine family to another and between intake and exhaust valves in the same engine. The area between the valve face and the head of the valve is called the margin. The margin allows for some machining of the valve face, which is sometimes necessary to restore its finish and allows the valve an extra capacity to hold heat.

The intake and exhaust valve heads are different diameters, the intake being the larger of the two. The size or diameter of the valves is determined by the engine design and its uses.

As mentioned, the stem guides the valve during its up and down movement and serves to connect the valve to its spring through its valve spring retainers and keepers. The stem rides in a guide which is either machined into the head or pressed into the head as a separate replaceable part.

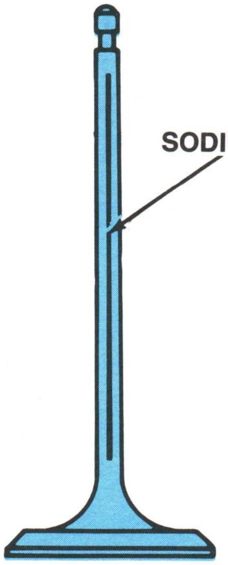
The valve seat is the area of the head contacted by the face of the valve. The seat may be machined into the head or it may be pressed in like the valve guide.



The valves found in today's modern engines are made from special high strength steel that is highly heat resistant. Heat resistance is very critical in exhaust valves as they must withstand working temperatures around 2250ºC (4000ºF). Heat resistance is much less a problem for intake valves as they receive extra cooling from the fuel mixture during the intake stroke.

There are two ways for the exhaust valve to rid itself of its heat. First, when the valve face is in contact with its seat, the heat from the valve will be transferred to the cylinder head, which is liquid cooled. The second is through the valve stem to the valve guide and again to the cylinder head. To aid in this second method of heat transfer, some exhaust valve stems are hollow. This hollow section is filled with sodium. Sodium is a silver-white alkaline metallic chemical element which transfers heat much better than steel. *Use caution with sodium filled valves, never cut them open for any reason. Sodium will burn violently when it contacts the air.*

Machining or refacing of the valves must be done with care. The angle must be correct for good sealing, the width must be correct for good heat transfer, and margin must not be too small as this would affect the valve's ability to hold heat.



EXHAUST VALVE

VALVE SEAT

The valve seat is the area contacted by the valve face when the valve is in the closed position. Both intake and exhaust valves have seats. The valve seat area must be hard enough to withstand the constant closing of the valve and supply good heat transfer. Due to corrosive products found in the exhaust gas the seats must be highly resistant to corrosion. When the cylinder head material meets these requirements the seats are machined directly into it. When it does not, the seats are then made of material that will meet the requirements and the seats are pressed into the head.

As with the valve face, the seat will require its sealing area to be resurfaced. When resurfacing three angles must be maintained. The sealing surface is machined at nearly the same angle as the valve face. Machining this surface alone will make the seat too wide. A wide seat leaves areas for carbon to collect, which will affect valve operation and sealing. To eliminate this, the seat must be narrowed. This is done by machining a wide upper clearance and a narrow angle lower clearance. When the upper and lower clearances are correct, the valve seat will be the proper width.

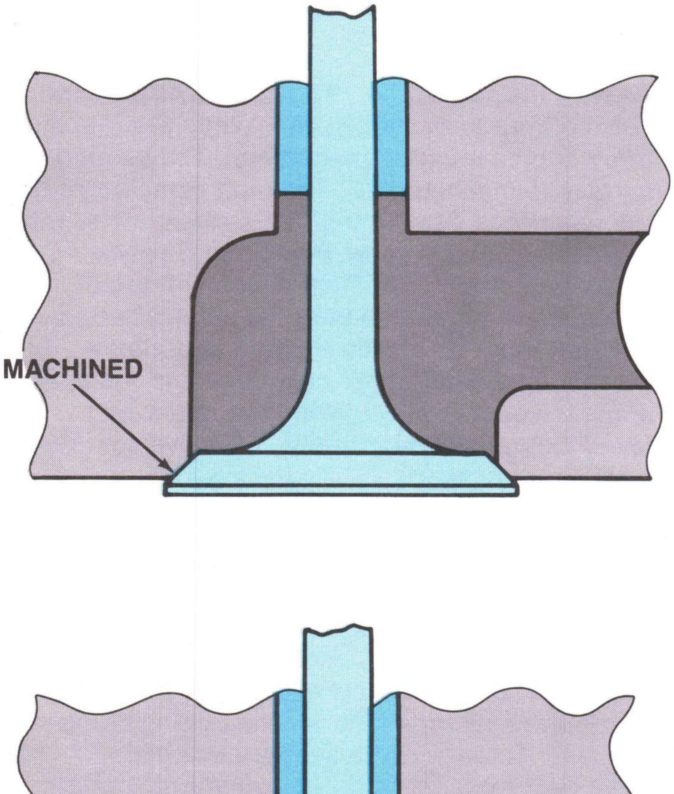
When grinding the valve seats, of all Ford engines, they must be at a true 45º angle. After the seat has been resurfaced use a seat width scale or a machinest scale to measure the seat width. Narrow the seat if necessary, to bring it within the specifications for the engine being serviced. To narrow the seat remove enough valve seat material from the top and/or bottom of the seat to bring the width into specification.

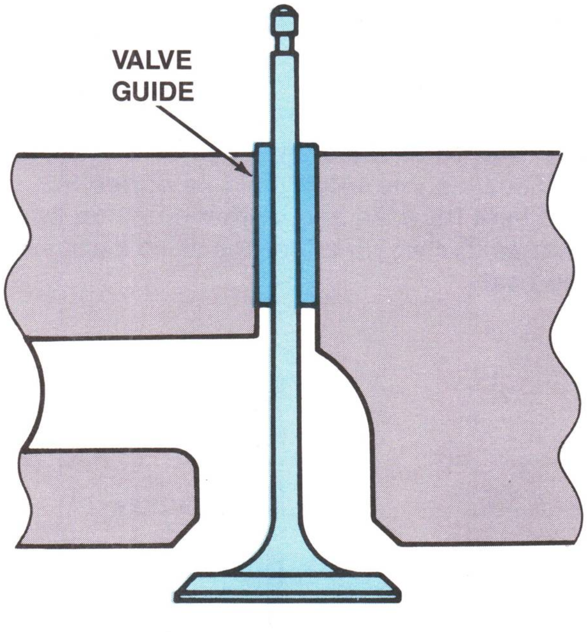
On intake valve seats, use a 77º grinding wheel to remove material from the bottom of the seat. For exhaust valves use a 70º wheel. Use an 18º wheel to remove material from the top of both the intake and exhaust valve seats. Removing material from the top of the seat will lower the seat contact with the valve face.

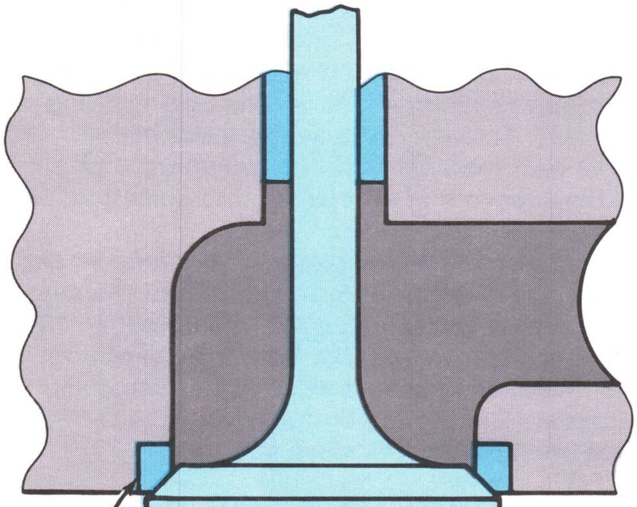
The finished valve seat should contact the approximate center of the valve face. This can be checked by coating the valve seat with Prussion Blue and setting the valve in place. Rotate the valve with light pressure. The blue should be transferred to the center of the valve face. If it is too high on the face, lower the valve seat by grinding its upper surface; if it is too low, grind its lower surface.

VALVE GUIDES

As with the valve seats, the guides may be machined into the head or they may be separate pieces which are pressed into the head. The valve stem moves up and down through the guides. The guide must be machined properly so that the valve will contact its seat accurately and must also have the proper clearance to ensure the valve stem is lubricated and to provide for heat transfer.







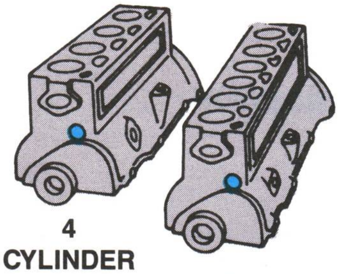
BASIC GASOLINE ENGINE

CAMSHAFT

The camshaft will be found in the block above the crankshaft on overhead valve engines. In overhead cam engines the cam is mounted in special cam towers fitted to or machined as part of the cylinder head. The camshaft resembles a series of eggs fastened together with the small end of each egg pointing in a different direction.

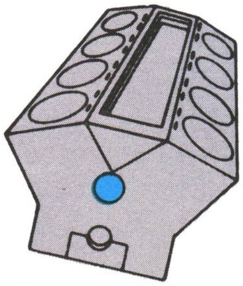
Most camshafts used in today's engines are made of cast iron, nodular iron or cast steel, and are hardened for long life. The egg shape is called the cam lobe. There are the same number of lobes as there are valves in an engine. For example a four cylinder engine normally has eight valves, the camshaft for this engine will have eight cam lobes.

Designing the camshaft for a given engine is a very exacting science. The positioning of the lobe on the shaft determines when the valve will open with relation to piston travel. The design of the lobe determines how high the valve will open and how long it will remain open. How high the camshaft will open the valve is called the valve lift. How long the camshaft keeps the valve open is called the duration. Valve lift and duration will vary from one engine family to another. It will also vary within the same family depending on the engine use. For example a certain engine family may be used in automobiles, trucks and for commercial use. Each would have a camshaft with a different design. Most automobile engines are equipped with a camshaft that will deliver a moderate lift and short duration. This design will allow smooth idling and good low speed torque. The same engine design for higher speeds, such as a racing engine, would use a cam with high lift and long duration. This configuration does not allow for smooth idling or good low speed operation.

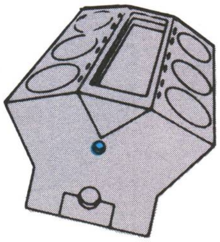


4 CYLINDER

6 CYLINDER

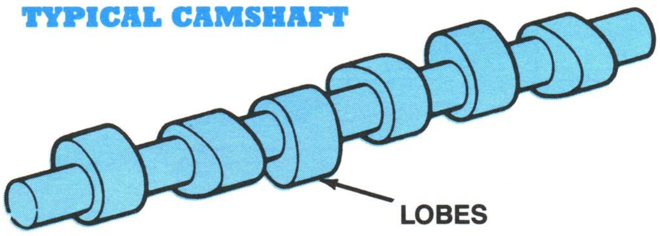


8 CYLINDER



6 CYLINDER

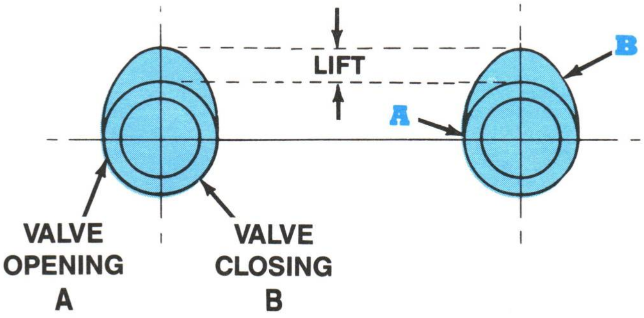
TYPICAL CAMSHAFT



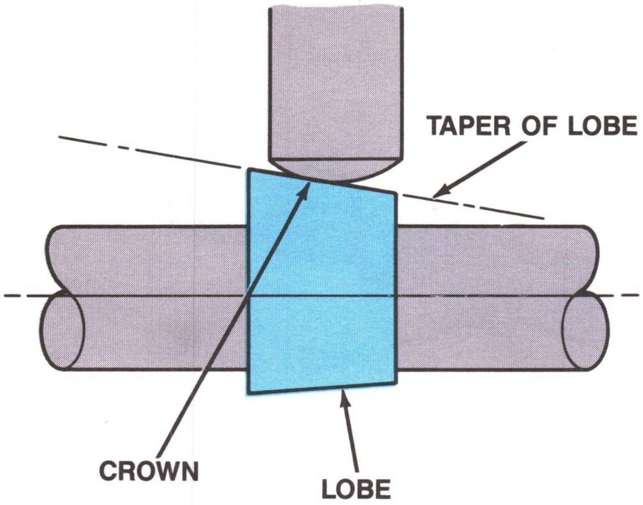
LONG DURATION

SHORT DURATION

LOBES

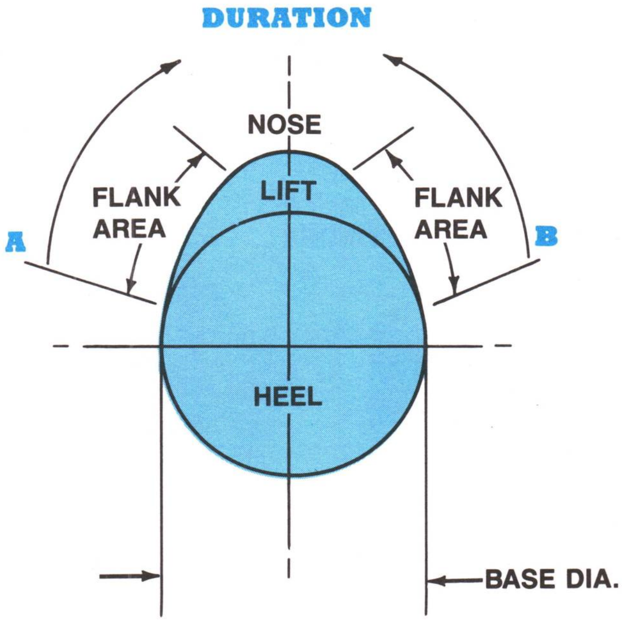


As you can see the designing of a camshaft is complicated, but there is still more. The camshaft must be designed to do its job properly, it also must last. The camshaft found in most late model automobiles use tapered lobes. The lobes can be tapered as much as 0.05 mm (0.002 inch) to as little as 0.017 mm (0.0007 inch). This taper provides for lifter rotation and spreads the load of the valve train against more of the lobe face. We will explain lifter rotation further on in this manual.



The proper nomenclature for a camshaft and lobe is:

- Diameter — The actual measurement of the camshaft base.
- Heel — The portion of the cam lobe contacted by the lifter when the valve is closed.
- Flank — There are two flanks, one for opening the valve, one for closing. The flank is the ramp between the cam base and its nose.
- Nose — The top or highest point of the cam lobe.
- Lift — The distance the lobe will move the lifter. This is measured from the base to the top of the nose.
- Duration — The distance from the start or the lift flank, across the nose to the heel of the closing flank. Measured in degrees of crankshaft rotation.



LIFTERS

Valve lifters or cam followers. They are found in a bore above each cam lobe. As there are the same number of lobes for each valve in the engine, there are also the same number of lifters.

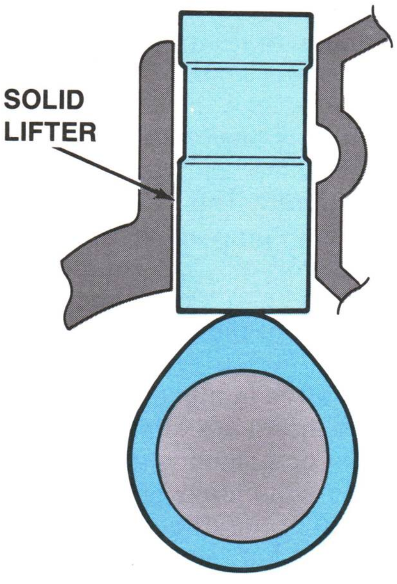
There are two basic types of lifter designs. The first is the solid or mechanical. The solid lifter is simply an iron cylindrical piece machined at one end to contact the cam lobe and at the other end to accept the push rod. There are no moving parts found in the solid lifter. Engines equipped with solid lifters require periodic adjustments to correct for wear in the valve train and to eliminate valve noise. This type of lifter is usually not found in today's automobiles. It is, however, still used in commercial and racing engines.

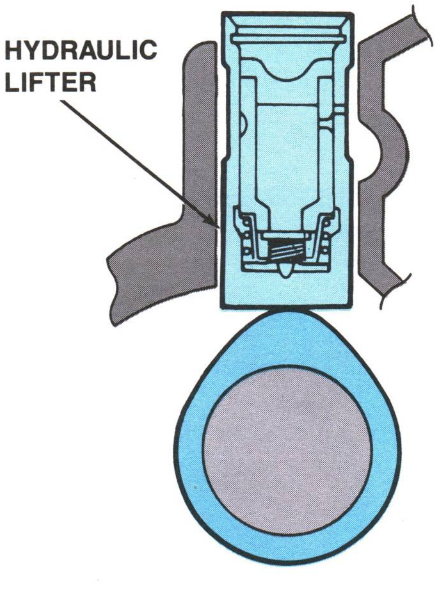
In most of today's engines, the solid lifter has been replaced by what is called the hydraulic lifter. The hydraulic lifter does not require adjustment as it uses oil under pressure to correct for any minor clearance that may develop in the valve train. This clearance is called "lash." Lash can be caused by wear to the valve train or by the simple expansion and contraction of the valve train components that may occur due to the heating and cooling of the engine.

The hydraulic lifter is one of the most highly engineered, precision engine components. In effect, it is a hydraulic cylinder which uses engine oil pressure and internal spring pressure to provide a quiet and snug valve train. The unit is contained in a hardened iron body. It is made up of:

- Plunger
- Oil metering disc valve
- Push rod seat
- Snap ring
- Check valve disc
- Check valve spring
- Plunger return spring

The base of the body is not flat, it is ground spherically with a slight crown in the center. This design aids in the lifter to lobe contact and causes the lifter to rotate as it circles up and down in its bore. By rotating, the lifter wear is more evenly spread over the face of the lifter and cam lobe.





When the lifter is on the heel of the cam, the spring under the plunger pushes the plunger up to eliminate any valve train lash. By pushing up the plunger the check valve in the lifter opens and engine oil under pressure fills the hydraulic cylinder. As the cam lobe begins to lift the lifter, the check valve closes trapping the oil under the plunger. The oil will not compress. The cam lobe pushes the lifter up and by means of the push rod and rocker arm the valve is open. As the camshaft continues to rotate the valve closes and the process starts again.

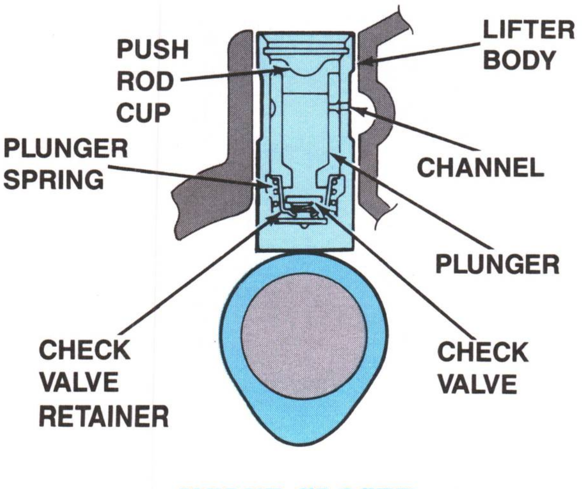
The hydraulic lifter is designed to have a very small amount of oil leakage between the plunger and lifter body. This is necessary to prevent lifter pump up. Pump up occurs when the lifter is overfilled with oil. This condition would cause the valves to open too far and could cause them to contact the piston.

When the camshaft is in place and the lifters are installed, the lifters are offset from the cam lobes. This offset combined with the taper of the cam lobe and spherically ground lifter body cause the rotation of the lifter necessary for long life of the camshaft and lifter. In use the lifter will wear to its bore and the face of the cam lobe. The push rod will wear to the lifter as well as the rocker arm. For this reason, if the engine is dismantled, all parts of the valve train must be kept in order and reinstalled in their same location.

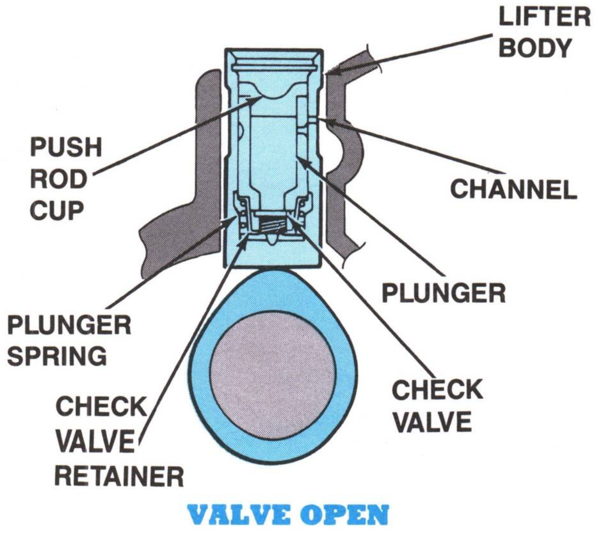
Clean engine oil system and clean technician work habits are a must when servicing the camshaft and hydraulic lifters.

There are several terms used with regard to the camshaft and valve parts. We will now list each and explain them to you.

- Valve Train — These are the parts necessary to transfer camshaft movement to valve movement. The parts involved are the lifter, push rod, rocker arm, and valve spring.
- Valve Timing — The valve timing is determined by the design of the camshaft. When and how much the valves open.
- Camshaft Timing — Camshaft timing is the relationship between the camshaft and the crankshaft. The camshaft is driven by the crankshaft directly, by means of gears or indirectly by means of a timing chain or timing belt. This relationship is critical and must be done with great care as it will affect total engine operation.



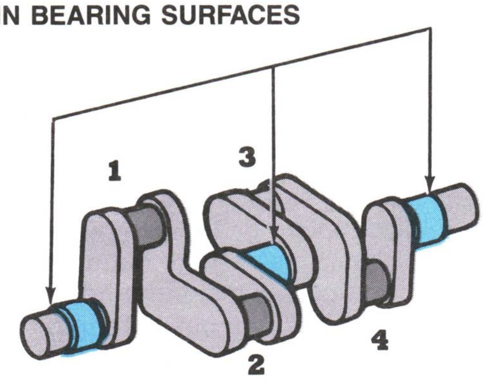
VALVE CLOSED

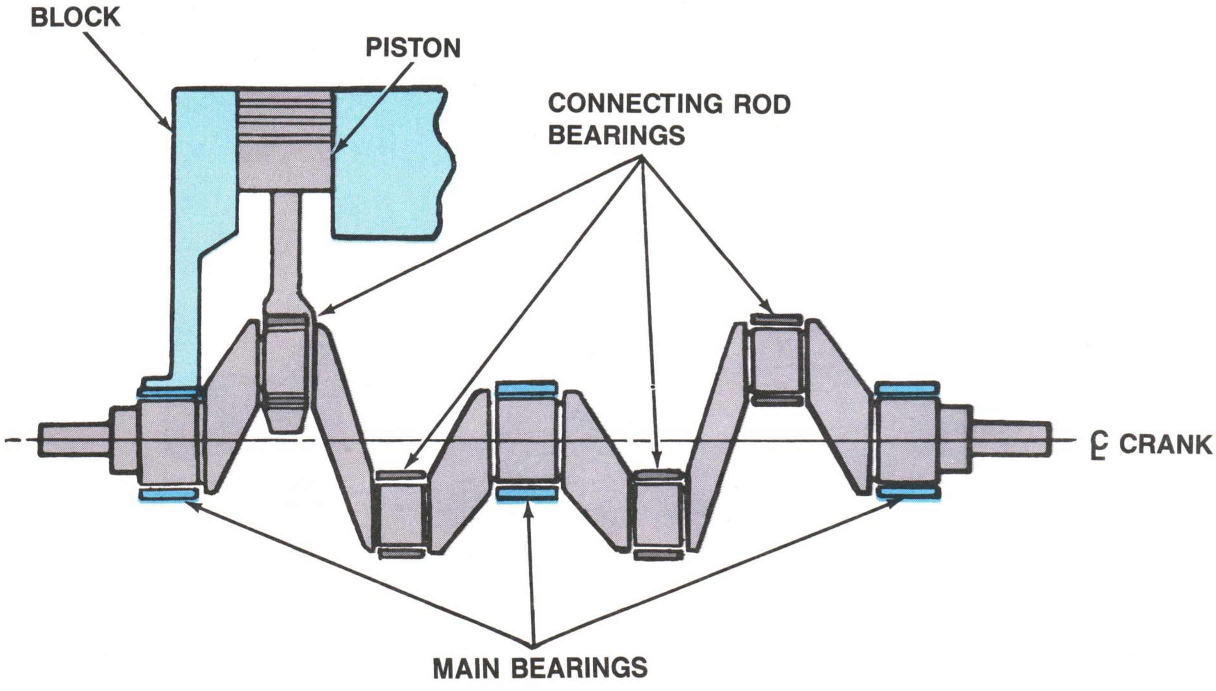


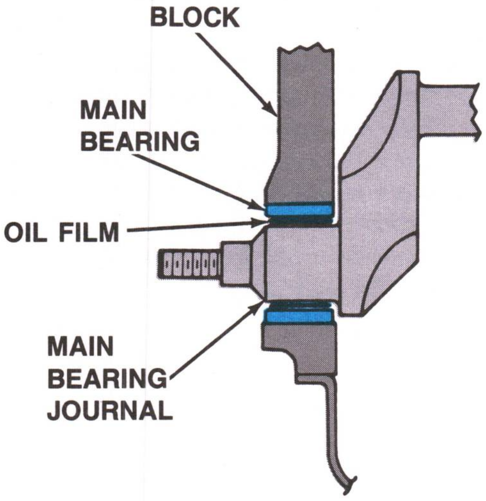
VALVE OPEN

CRANKSHAFT

The crankshaft is used to convert the up and down movement of the pistons to rotary movement which can be used to supply power. Crankshafts are generally made of cast iron, forged cast steel, nodular iron, and then machined. At the center line of the crankshaft are the main bearing journals. These journals must be machined to a very close tolerance as the weight and movement of the crankshaft will be supported at these points. The number of main bearings is determined by the design of the engine. V block engines generally have fewer main bearings than an in-line engine having the same number of cylinders. This is because the V block engine will use a shorter crankshaft. Offset from the crankshaft center line are the connecting rod bearing journals. The degree of offset and the number of journals is determined by the engine design. An engine having six cylinders in-line will have six connecting rod journals, a V8 engine will have only four as each journal will be connected to two connecting rods, one from each side of the V. The connecting rod journal is also called the crank pin. This area is machined to a very close tolerance just as the main bearing journal. The machining of the main and rod bearing journals must be done so as to have a very smooth surface at the bearing area. The bearings must fit tightly enough to eliminate noise, but must also have a clearance between them and their bearings for an oil film to form.





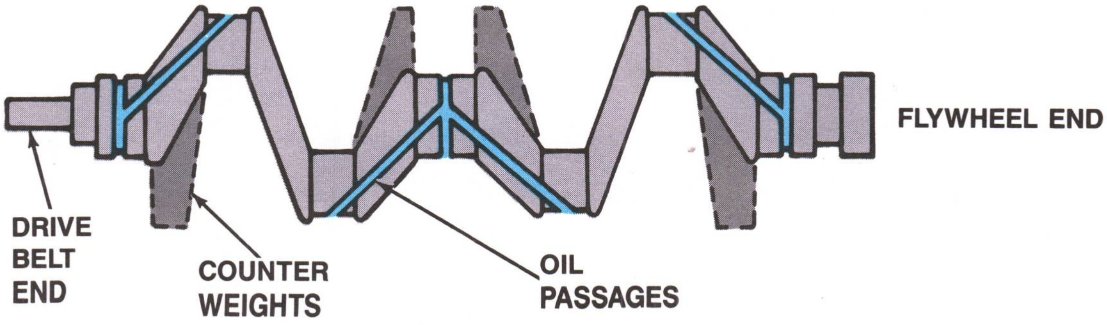


The crankshaft does not turn directly on the bearings. It turns on a film of oil trapped between the bearing surface and the journal surface. This oil is supplied by the engine's oil pump. We will cover this in more detail in the lubrication section of this manual. Should the crankshaft journals become out of round, tapered or scored, the oil film will not form properly and the journal will contact the bearing surface. This causes early bearing and/or crankshaft failure. The main and rod bearings are generally made of lead coated copper or tin aluminum. Both of these are softer material than that used to form the crankshaft. By using the soft material, any wear at the crankshaft journals will appear first on the bearings. Early diagnosis of bearing failure most often will spare the crankshaft and only the bearings will need to be replaced.

As mentioned earlier in this section the connecting rod journals are offset from the center line of the crankshaft.This puts weight and piston pressure off center on the crankshaft. To balance this for smooth engine operation counter weights must be added to the crankshaft, these weights may be cast as part of the crankshaft. They will be found opposite the connecting rod journals.

As we have mentioned the journals of the crankshaft must be smooth, highly polished. Bearings surround each journal and are fed oil under pressure. In order for the oil to reach these bearings oil passages must be drilled into the crankshaft. Each main bearing will receive oil under pressure from the pump. Each main bearing journal will have a hole drilled into it with a connecting hole or holes leading to one or more rod bearing journals. In this way all bearing journals receive oil under pressure to protect both the bearing and the journal.

The crankshaft has two distinct ends. One is called the flywheel end and as its name implies this is where the flywheel is connected to it. The front end or belt drive end of the crankshaft contains a threaded snout or is drilled and tapped. This is for attaching a vibration damper.

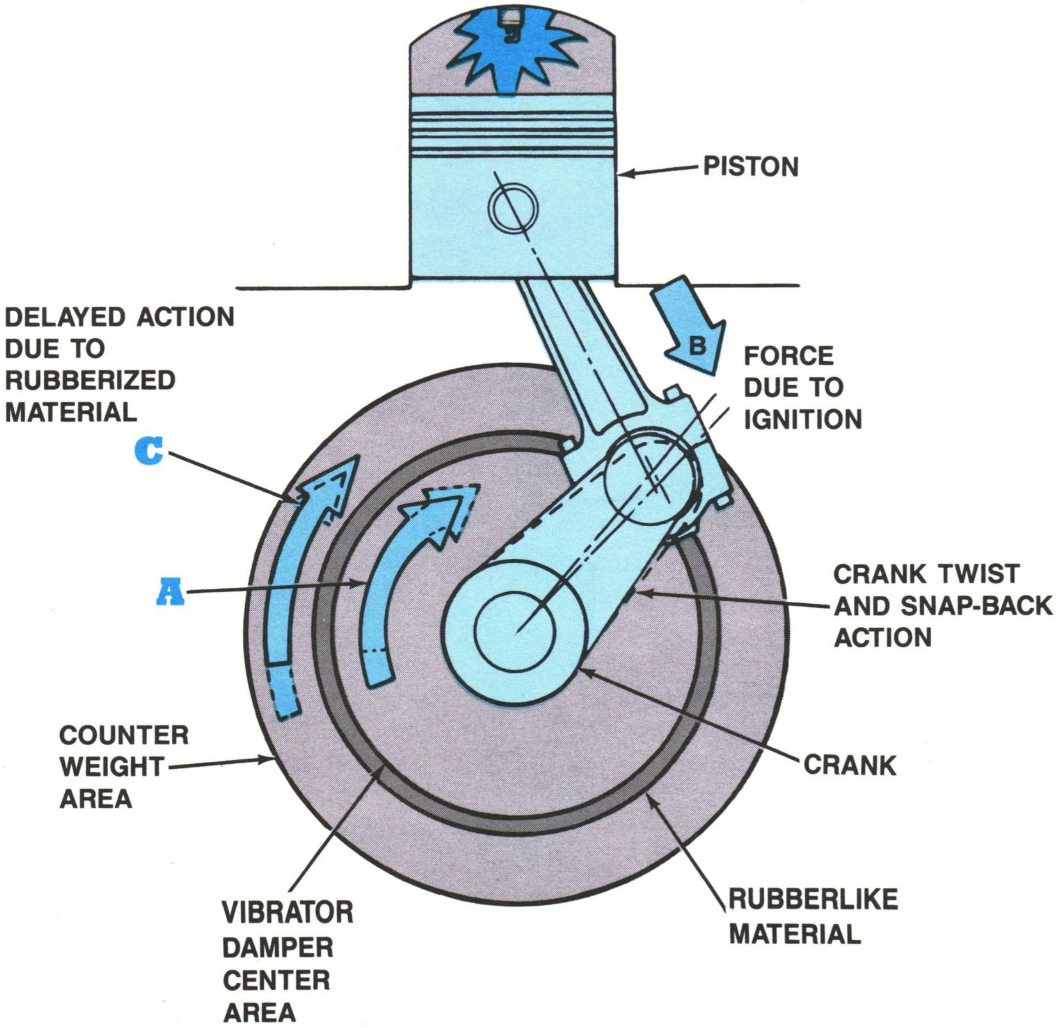


VIBRATION DAMPER

The purpose of the vibration damper is to dampen crankshaft vibration. Vibration is a back and forth motion. The crankshaft of a running engine will have a back and forth or twisting motion each time a cylinder fires. The force applied to the crankshaft can be more than two tons. This causes the crank to momentarily twist and snap back. The vibration damper consists of a center section, which is attached to the crankshaft. Surrounding the center section is a strip of rubber-like material. Attached to the material is a grooved counter weight. As the crankshaft twists, the center section "A" applies a force to the material. The material must then apply this force to the counter weight "C". The weight is snapped in the direction of the crankshaft rotation to counter balance the crankshaft connecting rod journal snapping back against the force due to ignition "B". The back and forth movement of the crankshaft is counter balanced by the back and forth movement of the vibration damper and the engine runs smoothly.

FLYWHEEL

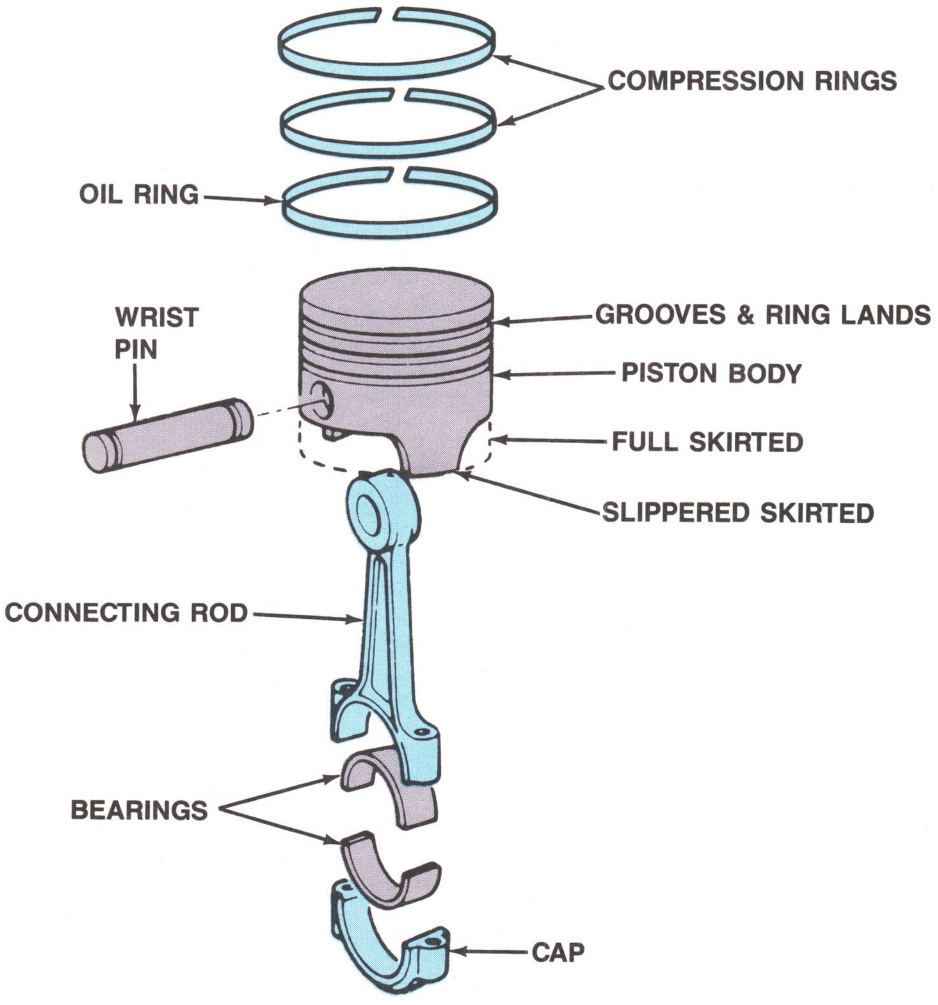
The flywheel also adds to the smooth running of the engine by applying a constant moving force to carry the crankshaft from one firing stroke to the next. Because of its large diameter the flywheel makes a convenient point for the starter to connect to the engine. The large diameter supplies good gear reduction for the starter making it easy for the starter to turn the engine against its compression.


PISTON
DELAYED ACTION DUE TO RUBBERIZED MATERIAL
C
B
FORCE DUE TO IGNITION
A
CRANK TWIST AND SNAP-BACK ACTION
COUNTER WEIGHT AREA
CRANK
VIBRATOR DAMPER CENTER AREA
RUBBERLIKE MATERIAL

PISTON

The piston forms the lower portion of the combustion chamber. The force of the expanding air fuel mixture at the time of ignition is exerted against the head or dome of the piston. This force then pushes the piston down in the cylinder. The force applied to the piston can be as high as two and one half tons in a gasoline engine. For this reason the piston must be very strong. In the past, pistons were made primarily of cast iron or a mixture of iron and steel. This type of piston is strong but is also heavy. Due to advances in aluminum technology, the pistons found in most modern automobile engines are now made of aluminum or aluminum alloy. Aluminum can be made strong enough to withstand combustion pressure and has the advantage of light weight. The aluminum piston's disadvantage is that it will expand more than the iron or iron and steel pistons. To counteract this, aluminum pistons usually have steel struts or inserts cast into them to help hold heat and contain the piston expansion.

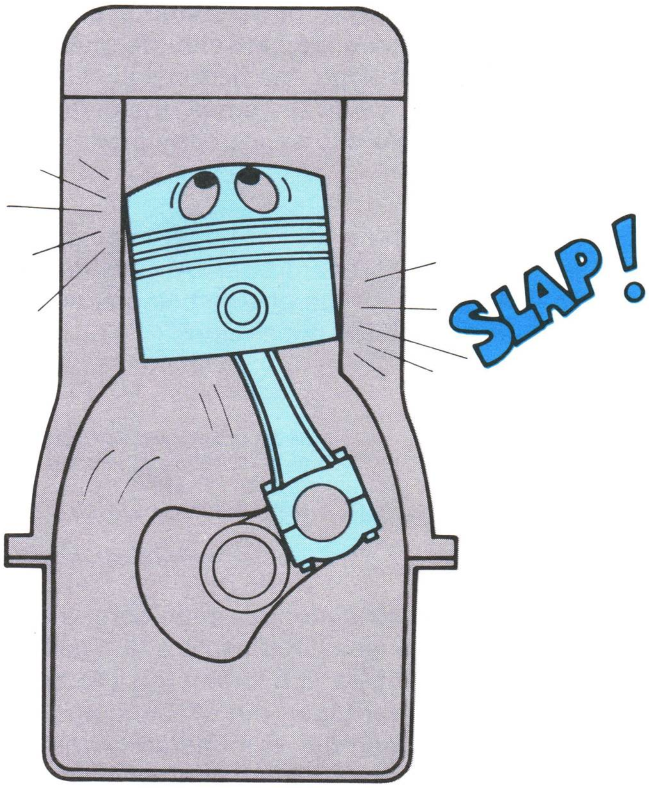
The top of the piston is called the head or dome, just below the dome on the side of the

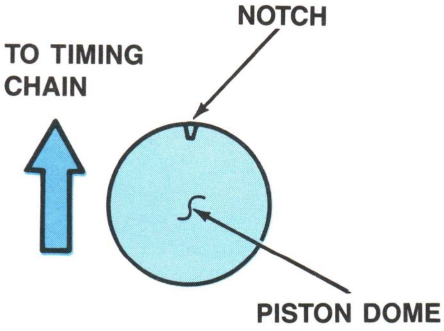


piston you will find a series of grooves. The grooves, sometimes called the ring lands, are used to contain the piston rings. Below the grooves you will find a bore, or hole, which is used for the piston pin, sometimes called the wrist pin. The pin is used to connect the piston to the connecting rod. This hole is not centered in the piston, it is off-set to one side. The piston pin offset is toward the major thrust side of the piston, the side that will contact the cylinder wall during the power stroke. By offsetting the pin, piston slap caused by the piston changing direction in the cylinder is eliminated.

The term piston slap is used to describe the noise made by the piston when it contacts the cylinder wall. This noise is usually heard only in older, high mileage engines that have worn pistons or cylinder walls.

To ensure the piston is installed correctly, so the offset is on the proper side, the top of the piston will contain a mark. The most common mark is a notch, machined into the top edge of the piston. This mark must always face the timing chain end of the engine when the piston is installed. The base of the piston, the area below the piston pin, is called the piston skirt. The area from just below the bottom ring groove to the tip of the skirt is the piston thrust surface. You will find two basic types of piston skirts, the slipper type and the full skirt. The full skirt is used primarily in truck and commercial engines, with the slipper type used for automobile engines. The slipper type skirt allows the piston enough thrust surface for normal operation and has the advantage of allowing the piston to be lighter. This design also cuts down on piston expansion as there is less material to hold heat. When an engine is designed, the piston expansion determines how much piston clearance will be needed in the cylinder bore. Too little clearance will cause the piston to bind at operating temperature, too much will cause piston slap. The normal piston clearance for an automobile engine, using slipper skirted pistons would be about 0.025 to 0.05 mm (0.001 to 0.002 inch). This clearance is measured cold between the piston skirt and the cylinder wall.





Because of this necessary expansion clearance the piston does not seal the combustion area. This is the job of the piston rings. The piston clearance also supplies a space for the piston lubrication.

PISTON FITTING

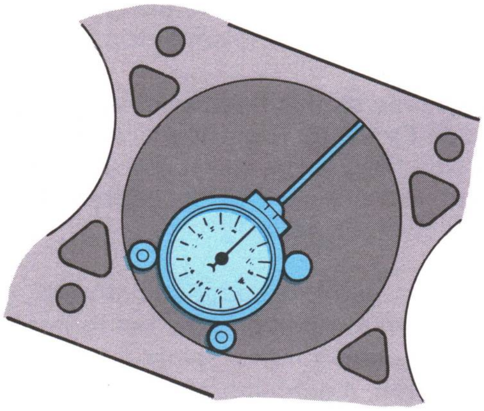
The fitting or matching of the piston to its cylinder bore is a very important step in engine servicing. If the clearance between the piston and cylinder is too large, the piston will "slap," should the clearance be too small, the piston will bind in the bore and cause early piston failure.

Standard bore pistons for Ford built engines are available in three standard sizes. Always refer to the specifications for the engine being serviced for the standard piston dimensions.

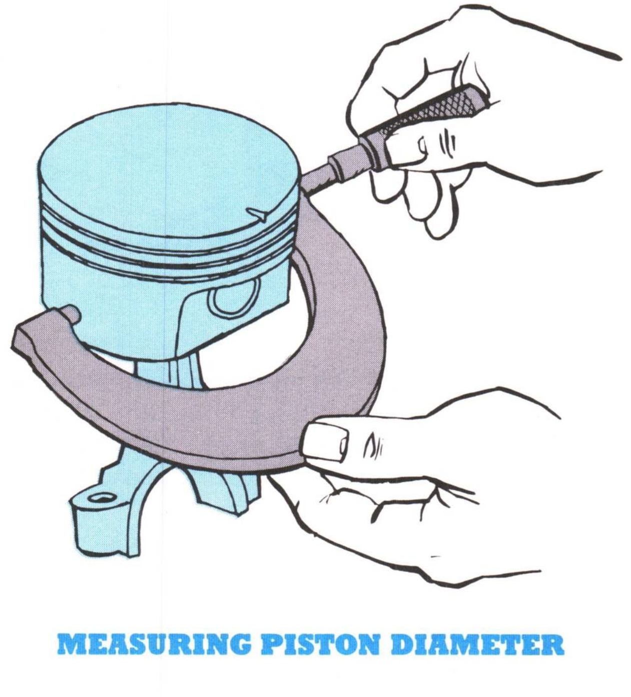
PISTON	
Diameter	
Coded Red	96.761-96.777 mm (3.8095-3.8101 in.)
Coded Blue	96.791-96.807 mm (3.8107-3.8113 in.)
0.1 mm (0.004 in.) Oversize	96.821-96.837 mm (3.8119-3.8125 in.)
PISTON-TO-BORE CLEARANCE	0.036-0.056 mm (0.0014-0.0022 in.)

To select the proper piston for each bore, the bore must first be measured using a dial gauge or a telescope gauge and micrometer. The bore must be checked for taper, out of round and diameter. If taper and out of round are within specifications on the engine being serviced, select a standard piston which will allow the proper piston to cylinder wall clearance. Always refer to the service manual for the engine being serviced. Follow the procedures as outlined for piston fitting to ensure good piston fit without piston "slap."

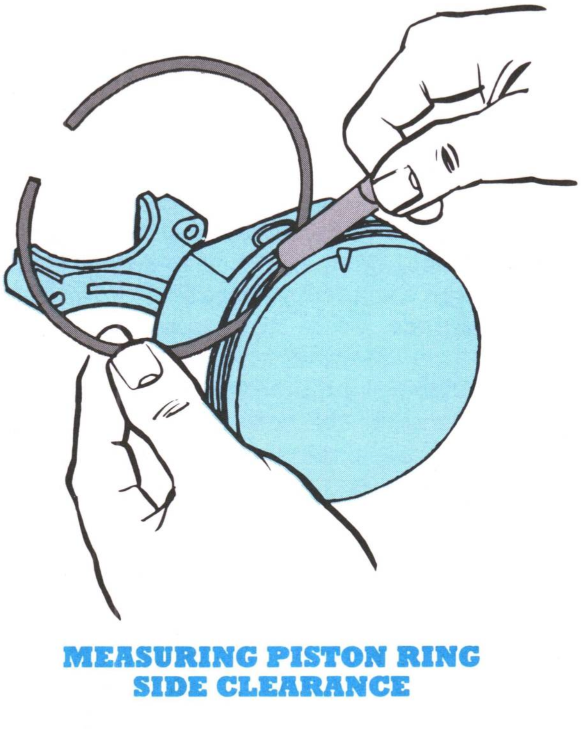
Once the piston has been properly fit to its bore, mark it so as to install it in the proper bore when assembling the engine.



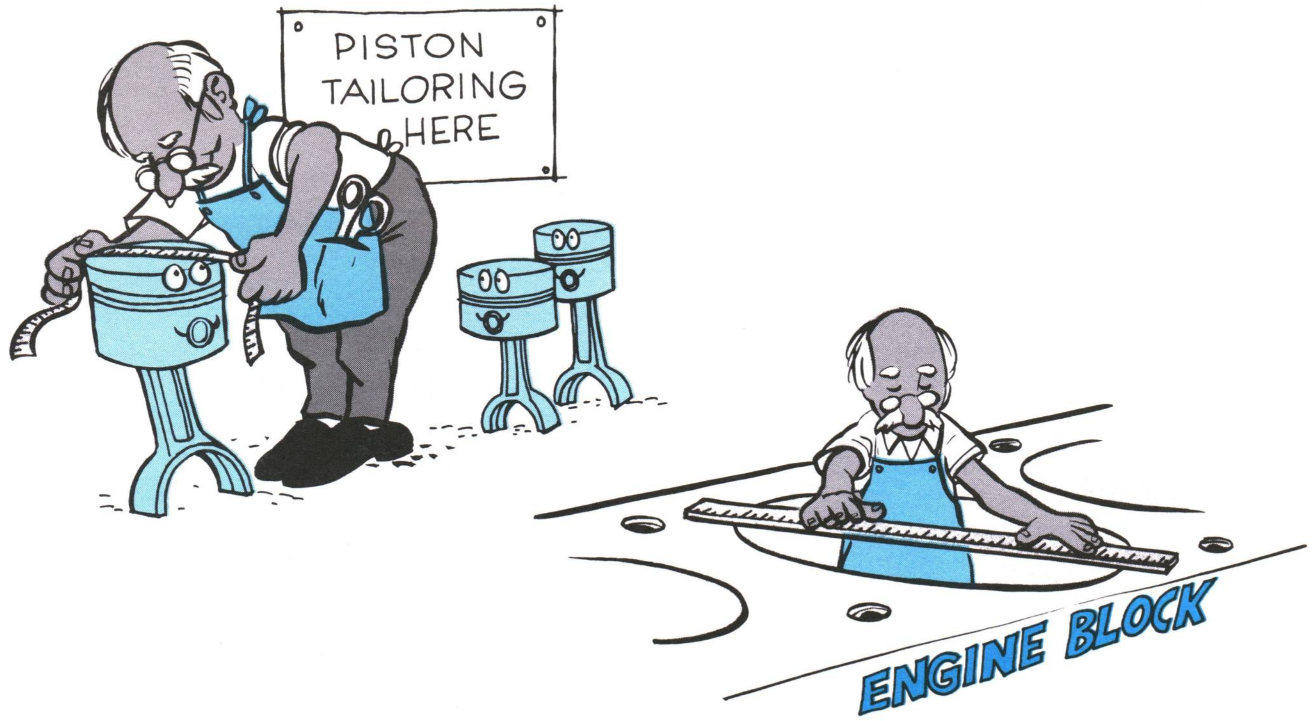
MEASURING CYLINDER BORE



MEASURING PISTON DIAMETER

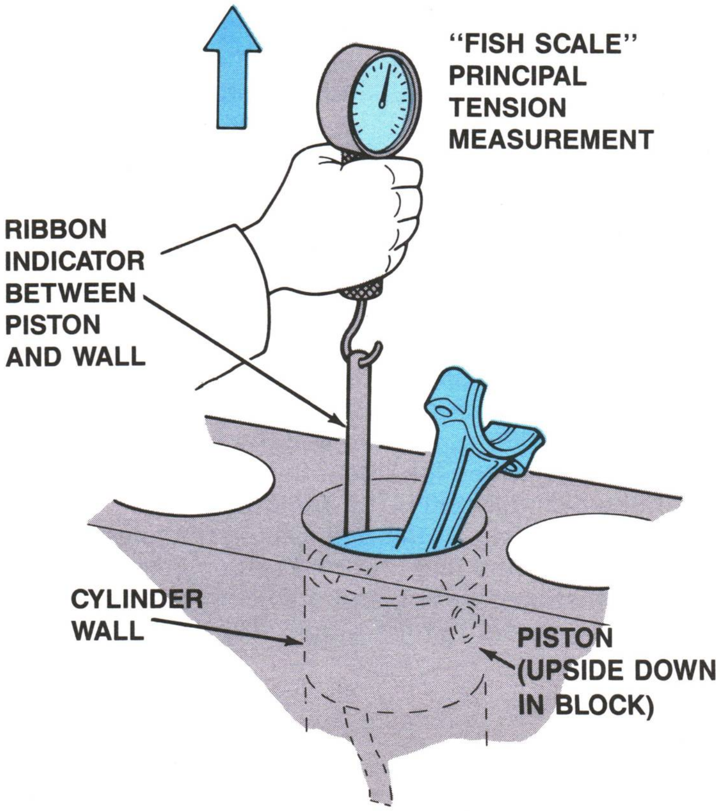


MEASURING PISTON RING SIDE CLEARANCE



A second method of checking piston clearance is by use of a 13 mm (.050 one half inch) wide feeler ribbon and a spring type pull scale. This check is made by installing the feeler ribbon in the cylinder along one of the thrust sides. Install the piston upside down in the cylinder with a thrust face centered against the ribbon. (The piston thrust surface is 90° from the wrist pin hole.) Push the piston down into the lower part of the cylinder. With the piston in this position the feeler ribbon must be centered between the piston thrust face and a thrust side of the cylinder, if it is not an incorrect measurement will be taken. Pull the feeler ribbon from between the cylinder and the piston using the pull scale. The spring scale readings are part of the specifications supplied by piston and engine manufacturers. The thickness of the ribbon that can be removed with the specified pull is the piston clearance.

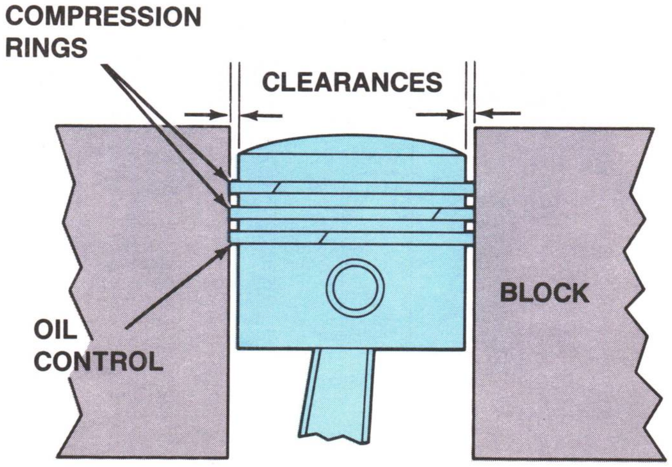
This method of piston fitting should be used only if the cylinder wall is not tapered or out of round. The clearance may be used to select the proper piston for each bore. Once the proper piston has been selected, mark it so as to install it in the proper bore when assembling the engine.



PISTON RINGS

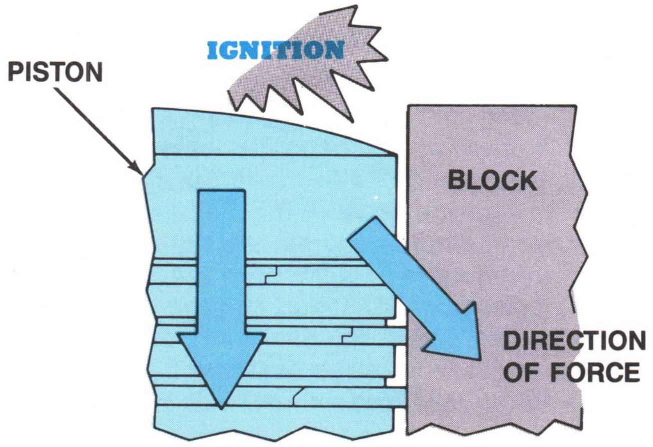
Piston rings are used to fill the necessary expansion gap between the piston and cylinder wall. It is the piston rings that seal the combustion chamber at the piston. In all, the piston rings must serve three functions:

- Rings seal the combustion chamber at the piston.
- Rings are used to remove oil from the cylinder walls. This is necessary to keep oil from reaching the upper cylinder where it will be burned.
- Rings carry heat from the piston to the cylinder walls to help cool the piston.



There are two basic ring families. They are the compression rings and the oil control rings.

In most modern automobile engines the pistons will be fitted with two compression rings and one oil control ring. The compression rings are found in the two upper grooves closest to the piston head. The oil ring is fitted to the groove just above the wrist pin.



We will first look at the compression rings. The compression rings form the seal between the piston and cylinder walls. They are designed to use combustion pressure to force the ring against the cylinder wall and against the bottom edge of the ring groove. The top ring is the primary seal with the second ring used to seal any small amount of pressure which may reach it. The compression rings are also used to remove excess oil from the cylinder walls and aid in cooling the piston carrying its heat to the cylinder walls.

During the power stroke, the pressure caused by the expanding air fuel mixture is applied between the inside of the ring and the piston groove. This forces the ring into full contact with the cylinder walls. The same force is applied to the top of the ring forcing it against the bottom of the ring groove. The combination of combustion pressure and the compression ring join together to form a tight ring seal.

Compression rings are generally made of cast iron. They come in a number of variations in cross section design. Most compression rings have a coating on their face which will aid in the wear in process. Wear in, is the time necessary for the rings to conform to the cylinder wall. Typical soft coatings are graphite, phosphate, iron oxide and molybdenum. Some compression rings have a hard coating, such as chromium.

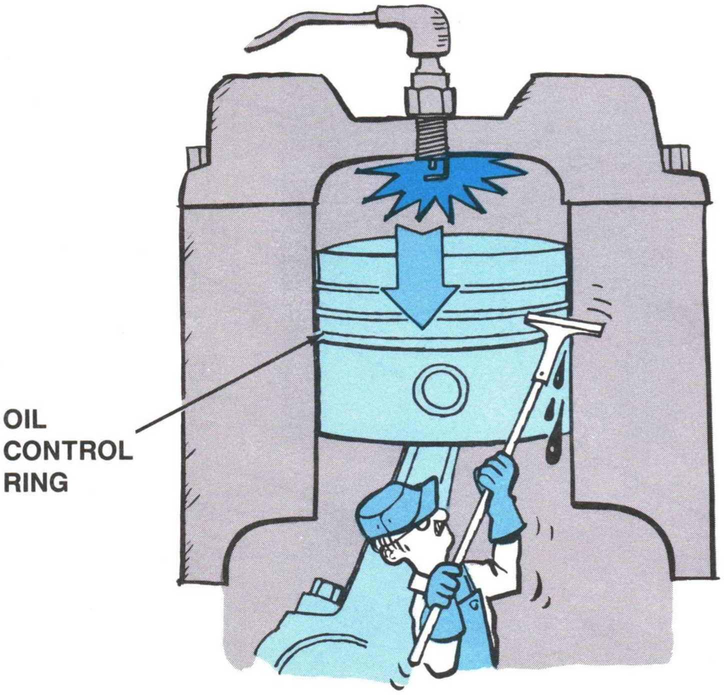
Just as the piston requires room for expansion, so do the rings. Ring expansion space is measured at the ring ends with the ring set at a certain point in the cylinder. This is commonly called ring end gap. When checking ring end gap refer to the proper service manual for the engine being serviced. The manual will tell you the proper gap and point at which it should be measured.

In addition to ring end gap, each piston should be checked for top ring groove wear. Groove wear may be determined by installing a new ring in the groove to be checked. Then use a feeler gauge between the upper surface of the ring and the ring groove. If a 0.15 mm (0.006 inch) feeler gauge can be inserted between the ring and groove, the clearance is too great and the piston should be replaced.

We will now look at the oil ring. As we know, oil is constantly being applied to the cylinder walls. The oil is used for lubrication as well as to clean the cylinder wall of carbon and dirt particles. This oil bath will also aid somewhat in cooling the piston.

Controlling this oil is the primary function of the oil ring. The two most common types of oil ring are the segmented oil ring and the cast iron oil ring. Both types of rings are slotted so that excess oil from the cylinder wall can pass through the ring. The oil ring groove of the piston is also slotted. After the oil passes through the ring it can then pass through the slots in the piston and return to the oil sump through the open section of the piston.

Segmented oil rings are made up of three pieces, an upper and lower scraper and an expander. The scrapers and expanders are made of spring steel. Segmented oil rings are a free fit design. This means that the expander is larger than the diameter of the cylinder. They must be carefully compressed when installed. The expander is used to form a tight seal of the scrapers at the cylinder walls.

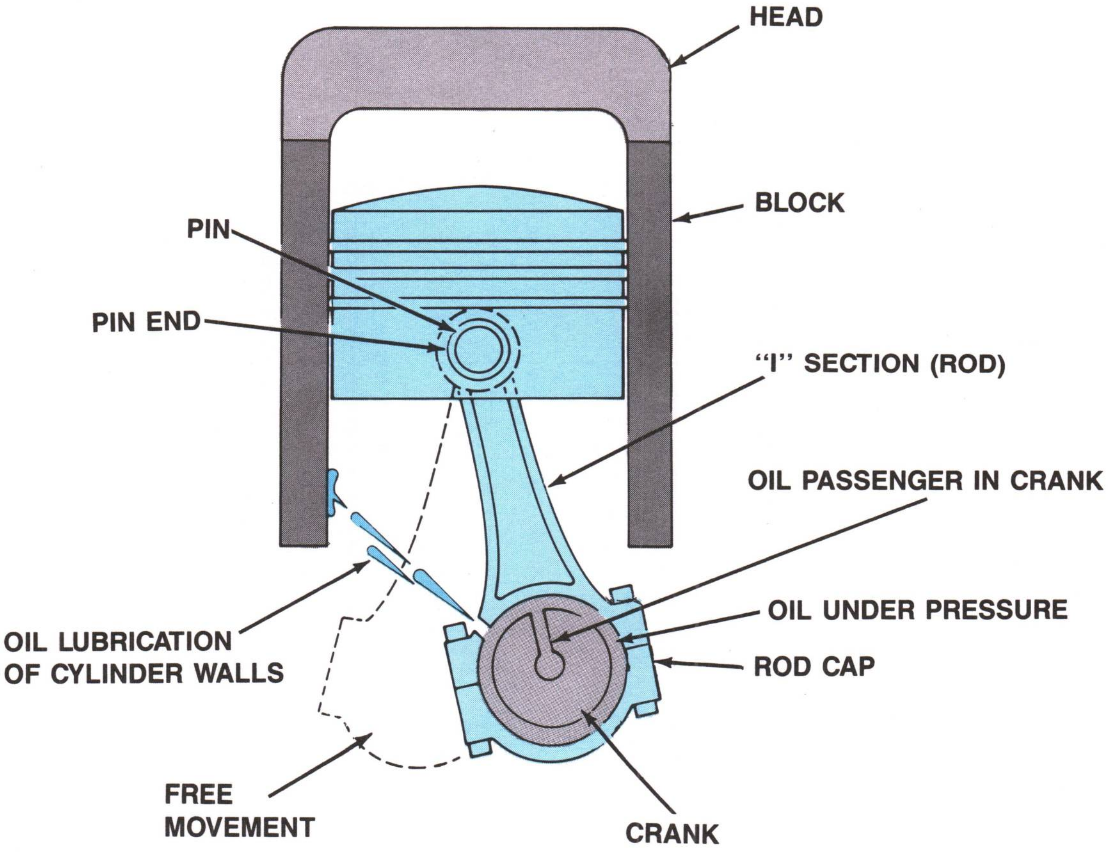


FUNCTION OF OIL CONTROL "WIPER" RING

CONNECTING ROD

The connecting rod is used to transmit the pressure applied on the piston to the crankshaft. The rod must be very strong, and at the same time be kept as light as possible. Connecting rods are generally forged from high strength steel. The center section is made in the form of an "I" for maximum strength with minimum weight. The small end or piston pin end is made to accept the piston pin. The pin is used to connect the piston and connecting rod. The rod must be free at the piston to move back and forth as the crankshaft rotates. The piston pin may be a force fit in the piston and free fit in the rod. When this is the case the small end of the rod will be fitted with a bushing. The pin may also be a free fit in the piston and force fit in the rod, in this case no bushings are used. The pin simply moves in the piston using the piston hole as a bearing surface. A third mounting allows the pin to move freely in both the piston and the rod. In this case the rod small end will contain a bushing and the piston will be fitted with a retainer at both ends of the piston pin. The retainers are used to keep the pin within the piston.

The larger end of the rod is used to attach the connecting rod to the crankshaft. This end is made in two pieces. The upper half is part of the rod, the lower half is called the rod cap and is bolted to the rod. The connecting rod and its cap are manufactured as a unit and must always be kept together. The large crankshaft end of the rod is fitted with bearing half shells made of the same material as the main bearings. If you will recall the crankshaft has oil passages which lead to the crank pins for lubricating the rod bearings. Connecting rods have a hole drilled through the big end to the bearing area. The bearing insert may have a hole which will align with this drilling. This hole is used to supply oil for lubricating and cooling the piston skirt. When the rod is properly installed the oil hole should be pointing to the major thrust area of the cylinder wall.



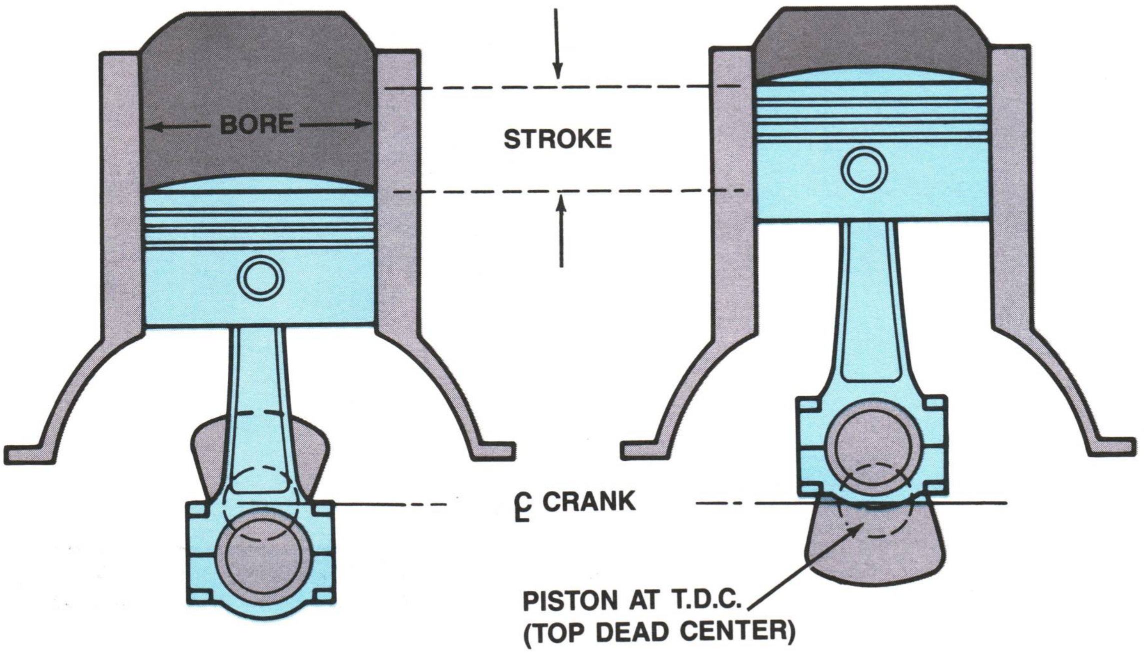
TERMS USED WITH THE FOUR STROKE CYCLE ENGINE

There are many terms used when discussing the four stroke cycle engine. We will list some of them here for quick reference.

- Bore — The diameter of a cylinder in any engine.
- Stroke — The distance the piston must travel from top dead center to bottom dead center within a cylinder.

C.I.D.	BORE & STROKE	B/S RATIO
289	4.00 x 2.87	1.39:1
302	4.00 x 3.00	1.33:1
351	4.00 x 3.50	1.14:1
390	4.05 x 3.78	1.07:1
400	4.00 x 4.00	1.0:1
427	4.23 x 3.78	1.11:1
428	4.13 x 3.98	1.03:1
429	4.36 x 3.59	1.21:1
460	4.36 x 3.85	1.13:1

- Bore and Stroke Ratio — This is the relationship between the bore and stroke of the engine. When the bore of the engine is larger than its stroke it is said to be over square. For example, an engine has a bore of 101.6 mm (4.00 inches) and a stroke of 72.89 mm (2.87 inches). It is considered over square. The bore and stroke ratio for this engine is 1.39. To find the bore and stroke ratio, you need to know the measurement of the bore and stroke, then simply divide the bore by the stroke. When the answer is one the bore and stroke are the same. When the answer is over one the bore is larger than the stroke, over square. When the answer is under one the stroke is larger than the bore, under square. Generally an over square engine will deliver high R.P.M., such as for automobile use, an under square or long stroke engine will deliver good low end torque, such as an engine for a truck or tractor.



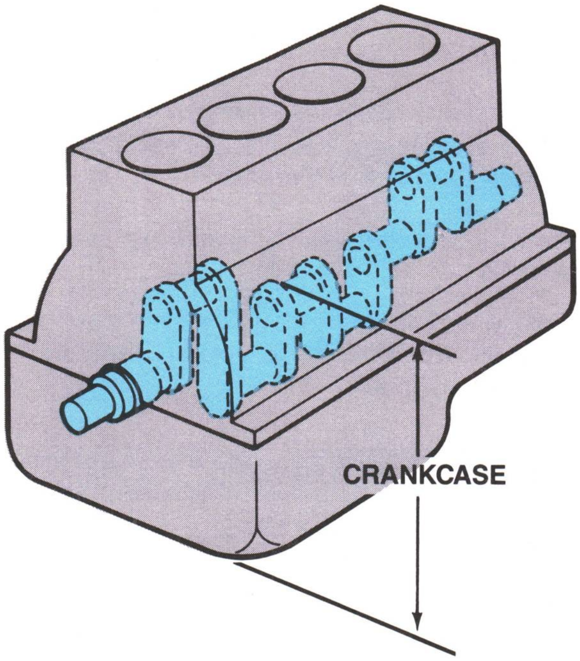
$$\frac{\text{BORE}}{\text{STROKE}} = \text{BORE STROKE RATIO}$$

BORE / STROKE RATIO

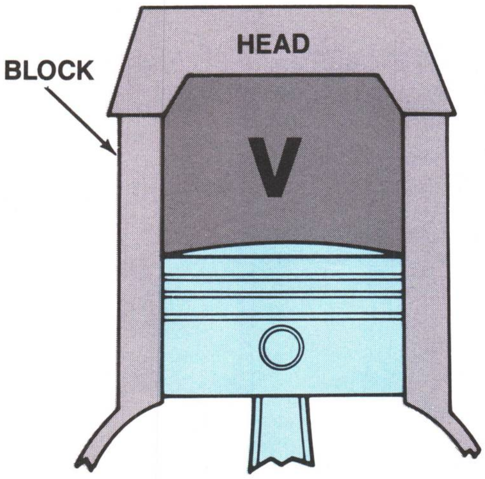
BASIC GASOLINE ENGINE

- Compression — The amount of force applied to the air fuel mixture in a cylinder.
- Compression Ratio — Compression ratio is the volume of the cylinder and combustion area with the piston at bottom dead center plus the volume of the cylinder and combustion area with the piston at top dead center divided by the volume of the combustion area and cylinder with the piston at top dead center. For example, the volume of the cylinder with the piston at B.D.C. is 575cc. The volume with the piston at T.D.C. is 75cc.

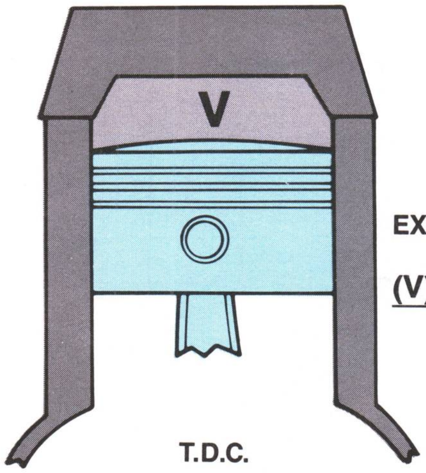
$$\frac{575\text{cc} + 75\text{cc}}{75\text{cc}} = 8.6 \text{ compression ratio.}$$



- Crankcase — The lower portion of the cylinder block that encloses the crankshaft.
- Sump — The oil pan which is bolted to the engine block at the crankcase.



B.D.C



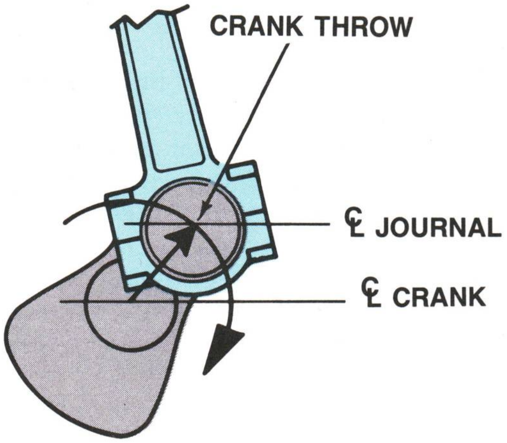
T.D.C.

EXAMPLE

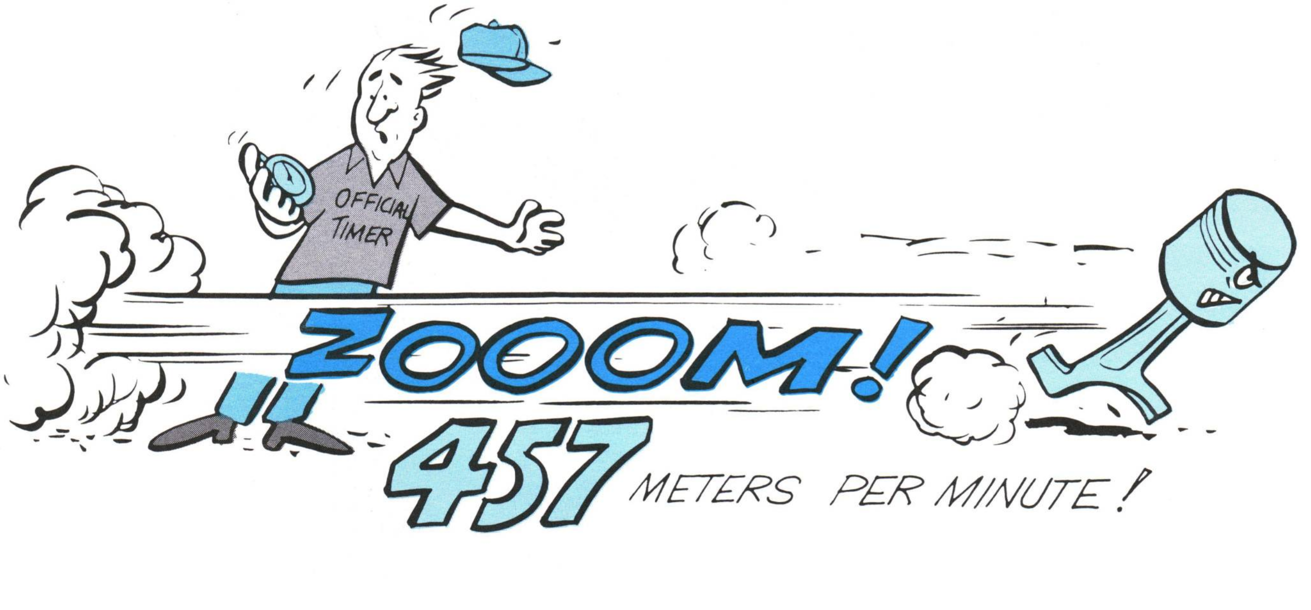
$$\frac{(V)\ 90 + (V)\ 10}{(V)\ 10} = 10{:}1$$

$$\frac{\boxed{V} + \boxed{V}}{\boxed{V}} = \boxed{\text{COMPRESSION RATIO}}$$

BASIC GASOLINE ENGINE



- Crank Throw — The distance from the crankshaft main bearing center line to the connect rod journal center line. The stroke of any engine is twice the crank throw.
- Valve Train — The components of an engine necessary to convert camshaft movement to valve movement.
- Flat Head Engine — Any engine with both intake and exhaust valves located in the cylinder block.
- Over-Head Valve Engine — Any engine with the camshaft located in the block and the intake and exhaust valves located in the cylinder head.
- Over-Head Cam Engine — Any engine with the intake valves, exhaust valves, and camshaft located in the cylinder head.
- Piston Speed — The average speed of a piston in meters or feet per minute, at a specified engine R.P.M. For example, an engine with a 76 mm stroke (three inches) will move its piston 152 mm (six inches) for each revolution. 76 mm (three inches) up and 76 mm (three inches) down. At 3000 R.P.M. the same engine will move one piston 457,200 mm (18,000 inches) or 457 m (1,500 feet) each minute. The longer the stroke the more the piston will travel and the more the piston speed will increase.

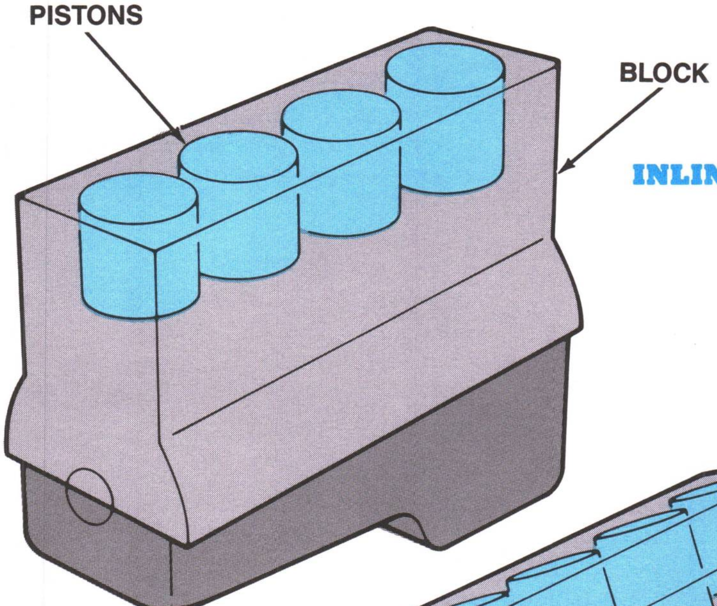

OFFICIAL TIMER
ZOOOM!
457 METERS PER MINUTE!

BASIC GASOLINE ENGINE

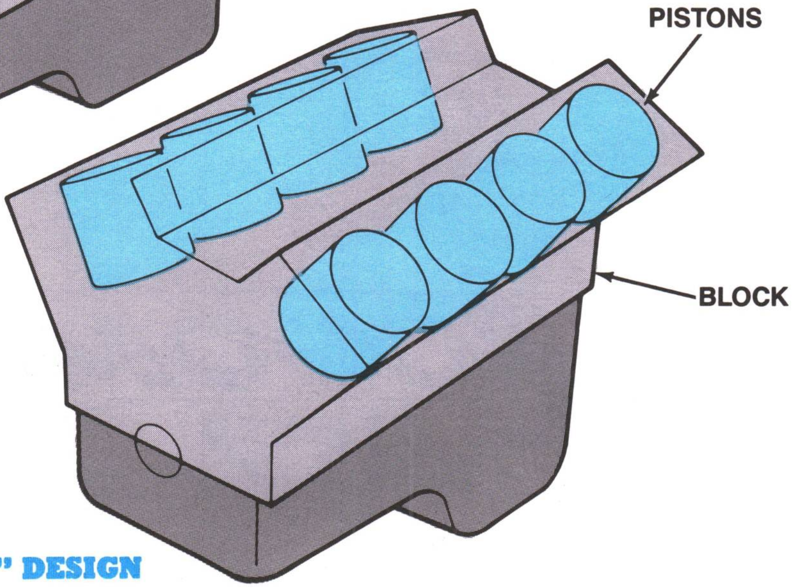
ENGINE CONFIGURATIONS

In today's modern automobile there are a large number of sizes and types of engines to choose from. There are engines to fit every need from small fuel efficient four cylinders to high performance V eights. All are produced on two basic block designs, the inline and the V. An inline engine has all of its cylinders formed in a straight line above the crankshaft. Inline engines are available in both four and six cylinder models. All have overhead valves and some have overhead camshafts.

The V block design comes in four, six and eight cylinder models, again all have overhead valves, with some special models having overhead camshafts. In V block engines with overhead cam design, there will be at least two camshafts used, one for each side of the V. A V block engine is one having its block cast in the form of a V, with half of its cylinders on each side set at an angle to the crankshaft. The most common angle being 90 degrees.



INLINE DESIGN



"V" DESIGN

BASIC GASOLINE ENGINE

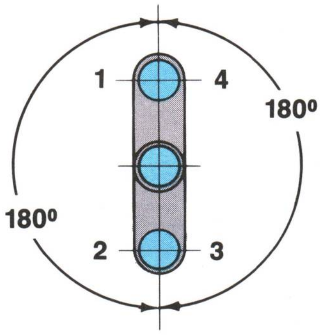
The crankshaft could well be called the backbone of the engine, as it ties together the reaction of all the pistons, transforms the reciprocating motion of the pistons and connecting rods into rotary motion. It then transmits the resulting torque to the flywheel. The crankshaft is a shaft with one or more throws or crank pins along its length. The arrangement of the throws is determined by the desired firing order of the engine.

Crankshafts are normally forged or cast from an alloy of nickel and steel. The rough casting or forging is then machined. When all the rough machining is completed, the non-bearing surfaces are plated with a light coating of copper. When the plating process is completed, the whole crankshaft is placed in a carburizing oven or electroinduction furnace, where surfaces of the crankshaft which are not copper coated become alloyed with the carbon. This will produce a thin hard surface or bearing area. This process is called case-hardening. The crankcase is completed by grinding the case-hardened surfaces.

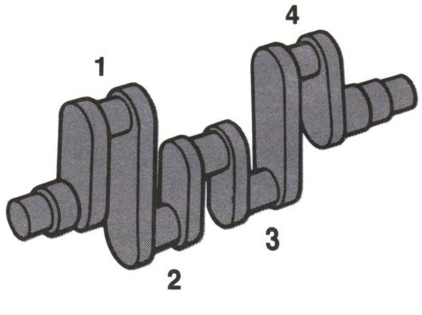
The crankshaft configuration determines the engine block design, or the positioning of the connecting rod journals around the centerline of the crankshaft. To better understand this we will first look at the crankshaft for a single cylinder engine. The crankshaft for a single cylinder engine has only one rod journal. Every 360 degrees it will return to top dead center. It requires two complete revolutions to complete its four strokes, so it will require 720 degrees between each power stroke. Now we add three more cylinders to create a four cylinder engine. We will also have to add three crank throws. To find the proper spacing for the throws, simply divide 720 by four. This gives us the proper spacing and a power stroke every 180 degrees. For an inline six we add two more cylinders, two crank throws and divide 720 again and find we have a power stroke every 120 degrees.

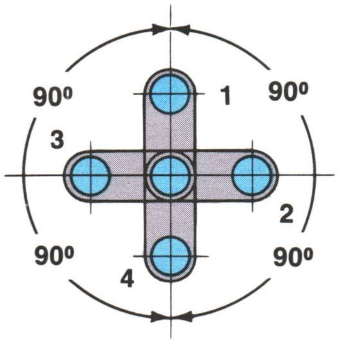
A V eight engine with a 90° V will have four crank throws as found in the four cylinder but there is a difference. The V eight will have two connecting rods per throw, one for each bank.

For the firing impulse of a V eight to be equally spaced the angle between the cylinder banks must be the same as the angle between the crank throws, or a multiple thereof. Actually this rule applies to any V type engine.

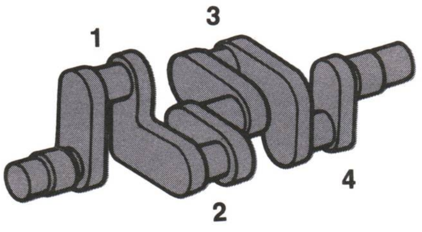


4 CYL.





V-8



BASIC GASOLINE ENGINE

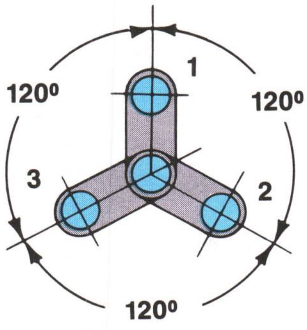
The V six engines that were first fitted to automobiles did not follow this rule. The block was a 90 degree design and the crank throws were spaced at 120 degrees. The engine would fire 90 degrees on one bank and 150 degrees on the other. The engine would continue firing this way and was known as the uneven fire V six.

Crankshaft technology has since smoothed out the V six. This was done by eliminating the common crank pin. The crank pins are now staggered on the even fire V six with a 30 degree off set separation between crank pins on the same throw.

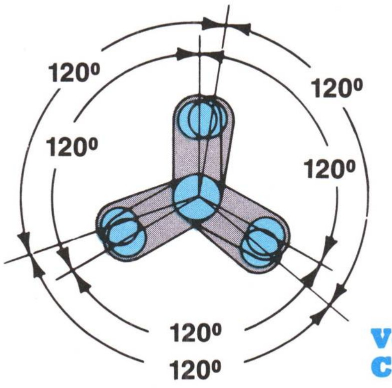
Crankshaft throw also determines camshaft design, what valve opens when, and the firing order of the engine, what piston is at T.D.C.

Any piece of rotating machinery has a certain definite speed at which it will start to vibrate excessively, this is called the critical speed. In designing a crankshaft, it is sometimes possible to place this critical speed outside the speed range of the engine. If not, the crankshaft must be heavy enough to withstand the vibration. In severe cases of vibration, the crankshaft may break. To run smoothly, a crankshaft must be statically and dynamically balanced. Crankshaft deflection caused by load stresses will often throw a crankshaft out of balance, especially at high speeds. To overcome vibration, uneven balance and load deflection, crankshafts are balanced by use of weights. These weights are forged as part of the crankshaft.

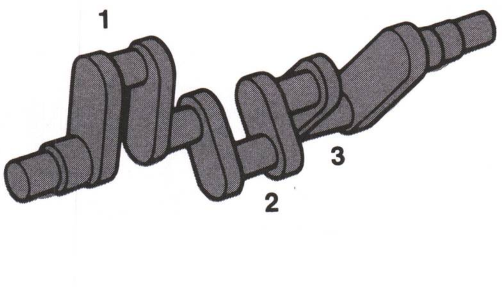
All vehicle manufacturers number each cylinder in an engine. Ford Motor Co. for example numbers its V eight engine one through four on the right bank and five through eight on the left. All American made inline engines are numbered in sequence with number one at the timing chain end of the engine. The firing order of any engine is the result of combining the numbering of the cylinders with the crank throw arrangement. The firing order is part of the engine design and never changes.

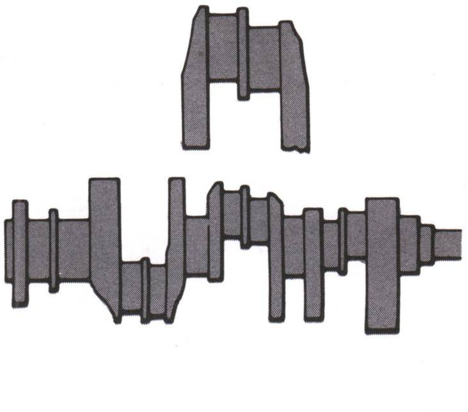


V-6



V-6 SPLAYED CRANKSHAFT PINS



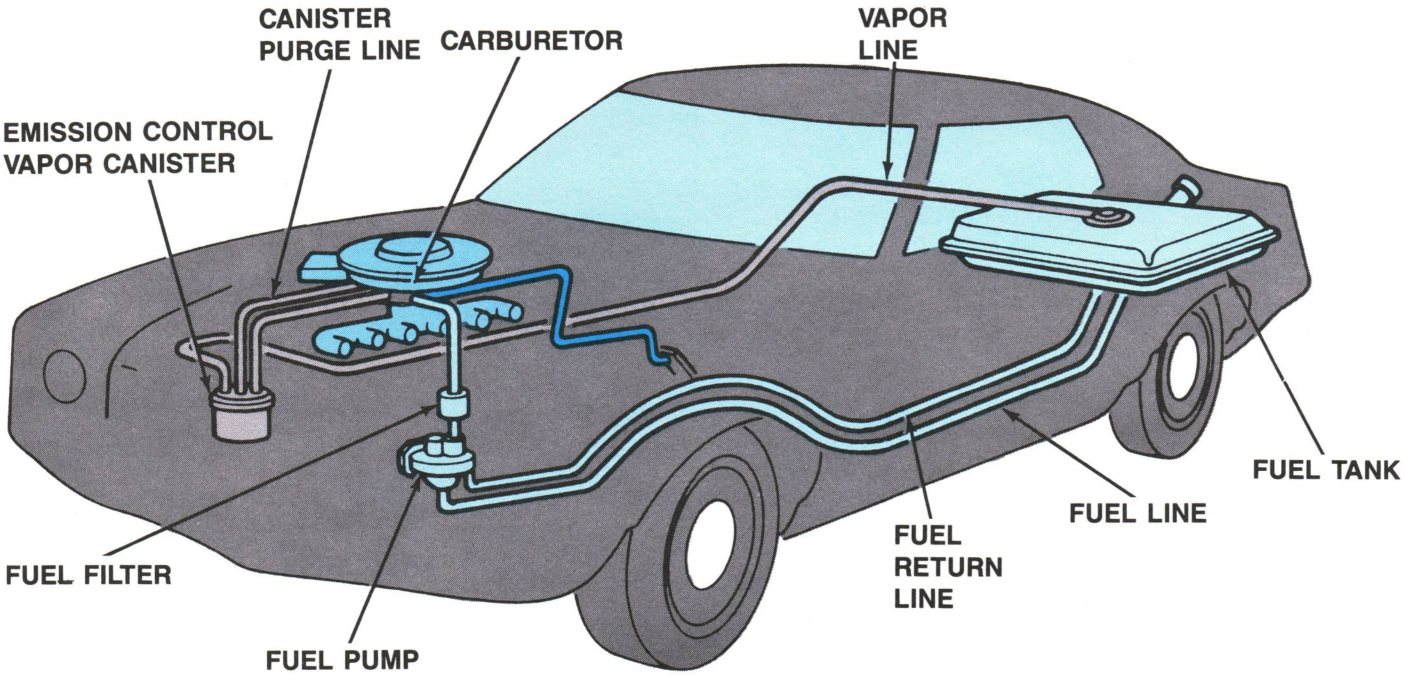


FUEL SYSTEM

The automobile fuel system must serve several functions, first it must be able to store fuel, second it must be able to move the fuel from the storage container to the engine, and it must blend the fuel with air in such a way as to be used by the engine.

The main components of a fuel system are the fuel tank, the fuel pump and a fuel delivery system. The fuel delivery system can be in the form of a carburetor or a fuel injection system. The secondary components of the fuel system are the fuel lines, fuel filters, flexible fuel line, air filter and the intake manifold.

First let's look at the fuel tank. The fuel tank is the container, it is built into the automobile and is designed to hold a reasonable supply of fuel. It is generally made of sheet metal and attached to the vehicle frame or mounted in the trunk area behind the rear seat. Fuel tanks contain some form of baffling to prevent the fuel from sloshing within the fuel tank. The fuel tank must contain a vent system which will relieve the pressure created by fuel expansion due to heat, and deliver an air supply to replace the fuel being removed by the fuel pump when the engine is running. In today's modern automobiles this venting system is sealed. A vent line is connected to the fuel vapor recovery canister, usually filled with activated charcoal. When the fuel expands due to heat, the fumes this creates will be held by the charcoal. When the engine is running fresh air will be drawn through the charcoal either by the line running to the intake manifold or by the line returning to the fuel tank. The air moving through the charcoal will purge it. Should this system become blocked, fuel expansion will distort the tank or fuel demand by the fuel pump and may cause the fuel tank to collapse.



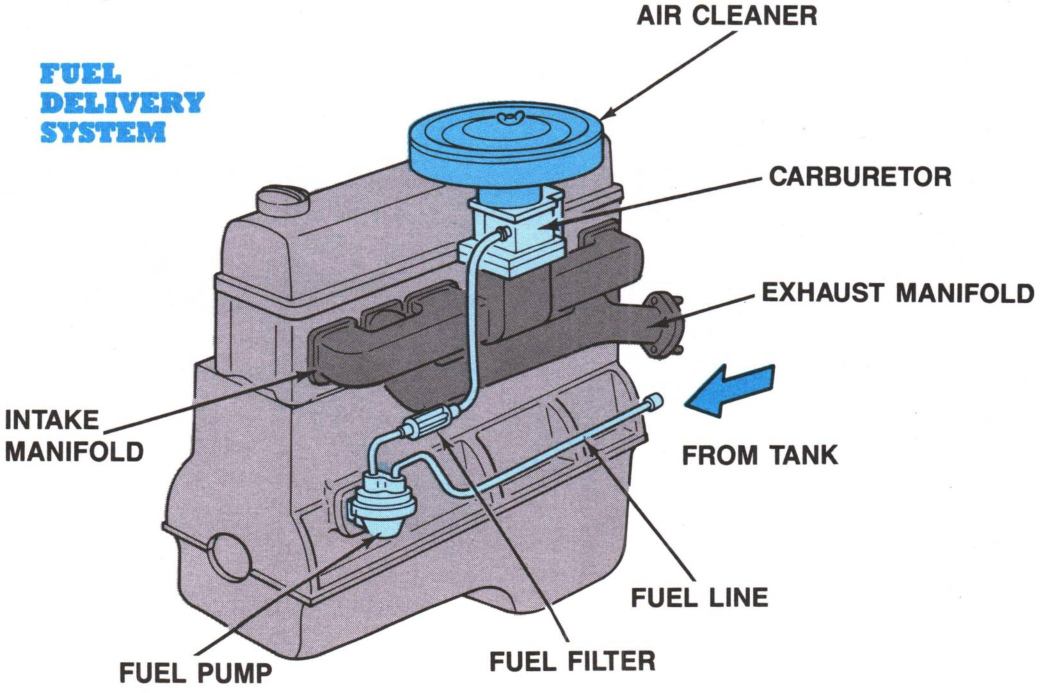
BASIC GASOLINE ENGINE

The fuel pump is used to draw fuel from the tank and supply it to the fuel delivery system. It must supply a sufficient amount of fuel at the correct pressure to meet the requirements of the engine under all operating conditions. The fuel pump can be operated electronically or mechanically by a special lobe attached to the camshaft. The fuel pump draws the fuel through a metal line from the fuel tank. The metal line does not connect directly to the fuel pump. A flexable line is installed between it and the fuel pump. In this way engine vibration is isolated from the metal fuel line. Between the fuel pump and the delivery system you will usually find a fuel filter. All fuel from the fuel pump must pass through the filter before reaching the delivery system. This filter is used to remove dirt particles from the fuel before it reaches the delivery system. This filter must be replaced at regular service intervals. Should the filter become blocked with dirt it will affect the engine operation. Some types of fuel filters are designed to hold water in suspension. This type of filter is generally used with fuel injection systems as water has a greater effect on them than it would have on a carburetor system. Should large amounts of water be found in the fuel system, the filter must be replaced. You cannot drain the water from it. It is also recommended to replace the fuel filter when servicing a carburetor.

Mounted at the air intake to the fuel delivery system will be some form of air filter assembly. The most common is the dry type with a replaceable element. On some applications you will find what is called an oil bath air cleaner. This unit uses oil to filter the air. This unit must be cleaned and the oil replaced at regular service intervals.

The main part of any fuel system is the fuel delivery or fuel metering system. This system must be able to deliver a good air fuel mixture to the engine during all starting and running conditions. It must deliver a rich mixture for starting, a good idle mixture and a leaner mixture for off idle running. It must do this automatically during all temperatures and engine running conditions. The two systems used today are the carburetor system and the fuel injection system. Both come in many different designs, all perform the same function, to deliver the proper amount of properly atomized air and fuel to meet the engine's requirements under all operating conditions.

FUEL DELIVERY SYSTEM



IGNITION SYSTEMS

The four stroke cycle gasoline engine operates by the forces generated by gases expanding within a combustion chamber. These gases are created by the burning of an air fuel mixture. For efficient operation the fuel mixture must be ignited at just the right point of piston travel. The fuel mixture must burn long enough to develop maximum power, and burn completely before the piston reaches B.D.C.

The fuel mixture is ignited by a high voltage spark. Producing this spark is the job of the ignition system. The ignition also must deliver this spark to each cylinder at the proper time.

There are different types of ignition systems found on automobiles, the most common are: the breaker point or standard ignition system and the electronic ignition system.

In today's automobiles the electronic ignition is widely used. To better understand its operation we will begin with a review of the Standard Breaker Point System.

A standard breaker point ignition system is a system that uses ignition points and a condenser to control current flow in the primary circuit. An electronic ignition system uses an electronic circuit to control current flow in the primary circuit.

When talking or reading about ignition systems, two terms are used often, they are primary circuit and the secondary circuit. Always remember the primary circuit carries low voltage, the secondary, high voltage.

To better understand the electronic ignition system, which is the most common today, we will first explain the standard system and refer to it when explaining the electronic system.

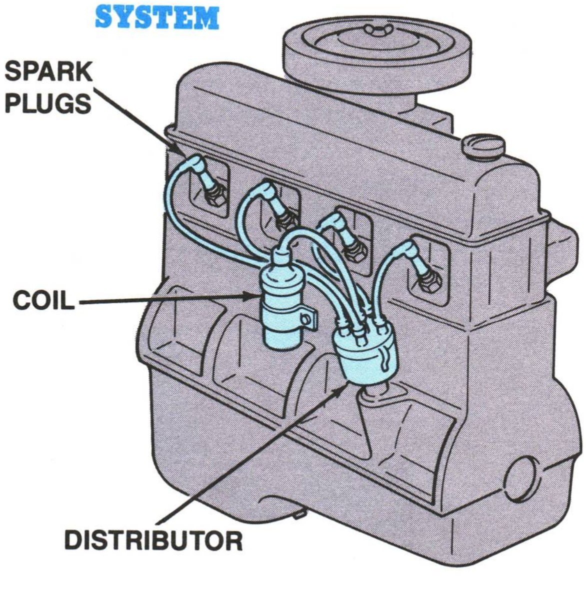
- Standard Ignition System
  The standard or breaker point ignition system has been with us since batteries were first installed in automobiles. It is considered by many to be a very simple system, because you can watch it work.

  The main components of the system are:

  - Battery
  - Ignition Switch
  - Ballast Resistor
  - Ignition Coil
  - Distributor Assembly
  - Primary Leads
  - High Tension or Secondary Leads
  - Spark Plugs

We will first see the purpose of each component, then the complete system operation.

IGNITION SYSTEM



BASIC GASOLINE ENGINE

BATTERY

The battery is used to provide the low voltage power necessary to produce current flow in the primary circuit.

IGNITION SWITCH

The ignition switch is in the primary wiring between the battery and ignition coil. It is simply an on-off switch used to control current flow in the circuit. When the switch is closed in the ON position, current flow reaches the coil.

BALLAST RESISTOR

The ballast resistor may be externally attached to the coil or may be in the form of a resistance wire.

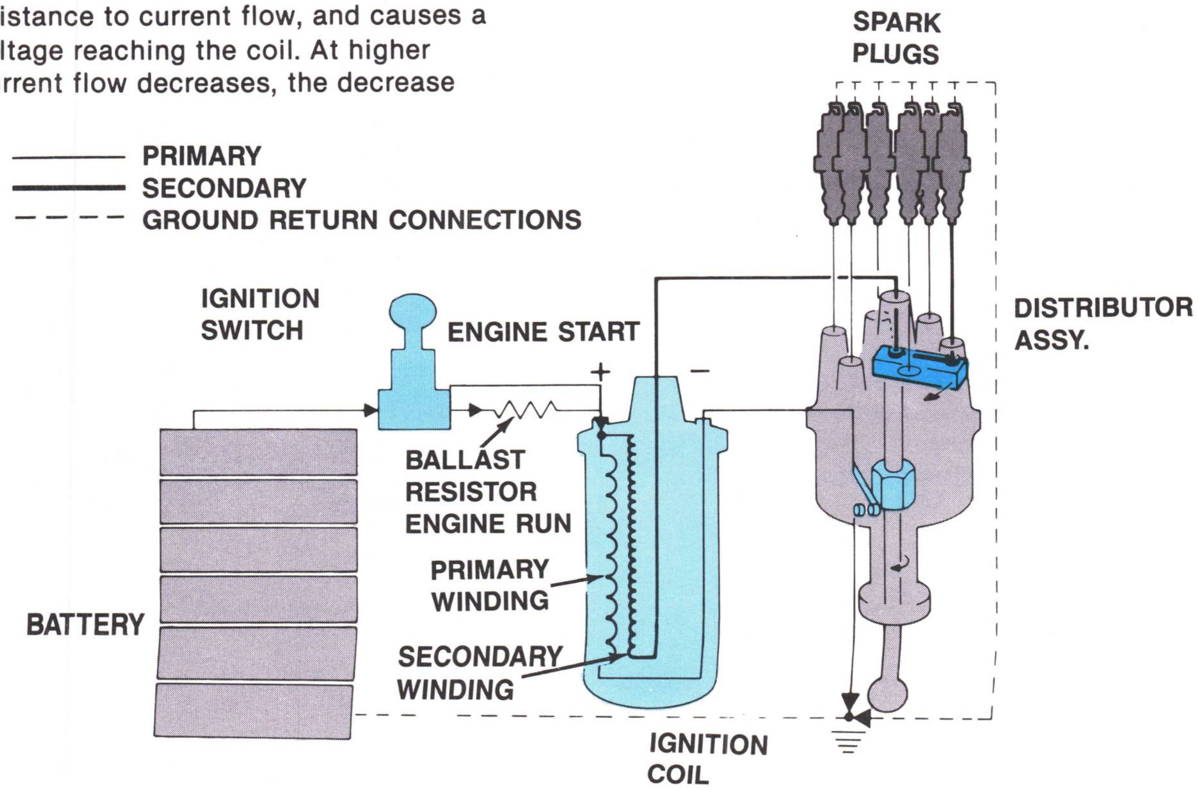
The ballast resistor is attached to the primary ignition circuit, between the ignition switch and the coil. The resistor is added to the circuit to compensate for variations in primary circuit current. These variations occur due to change in engine R.P.M. and load on the charging system.

At low engine speeds, current flow in the primary circuit is high. This high current flow causes heat in the resistor. The heat is caused by the resistance to current flow, and causes a drop in voltage reaching the coil. At higher speeds current flow decreases, the decrease causes the resistor to cool and about the same amount of voltage reaches the coil. The ballast resistor provides a balanced current to the coil during all speeds and load conditions. This balancing of current flow also increases the life of the ignition points.

It is possible to gain higher output from the coil if the resistor is removed. For this reason most systems will by-pass the resistor during starting. This assures a good current flow to the coil when the starter is engaged.

IGNITION COIL

The ignition coil transforms or increases battery voltage to a point high enough to bridge the gap of a spark plug. This build-up takes place between two windings within the coil. One winding is connected to battery and is part of the primary circuit. The second produces the high voltage necessary to fire the spark plug and is part of the secondary circuit.



DISTRIBUTOR ASSEMBLY

The distributor assembly is used to interrupt the flow of current in the primary circuit or the coil, and it distributes the high voltage developed in the secondary coil winding to each spark plug at the right time. The distributor assembly of the standard ignition system contains a cam, breaker plate, ignition points, and a condenser. This unit functions together mechanically, opening and closing the ignition points to interrupt the current flow in the primary circuit.

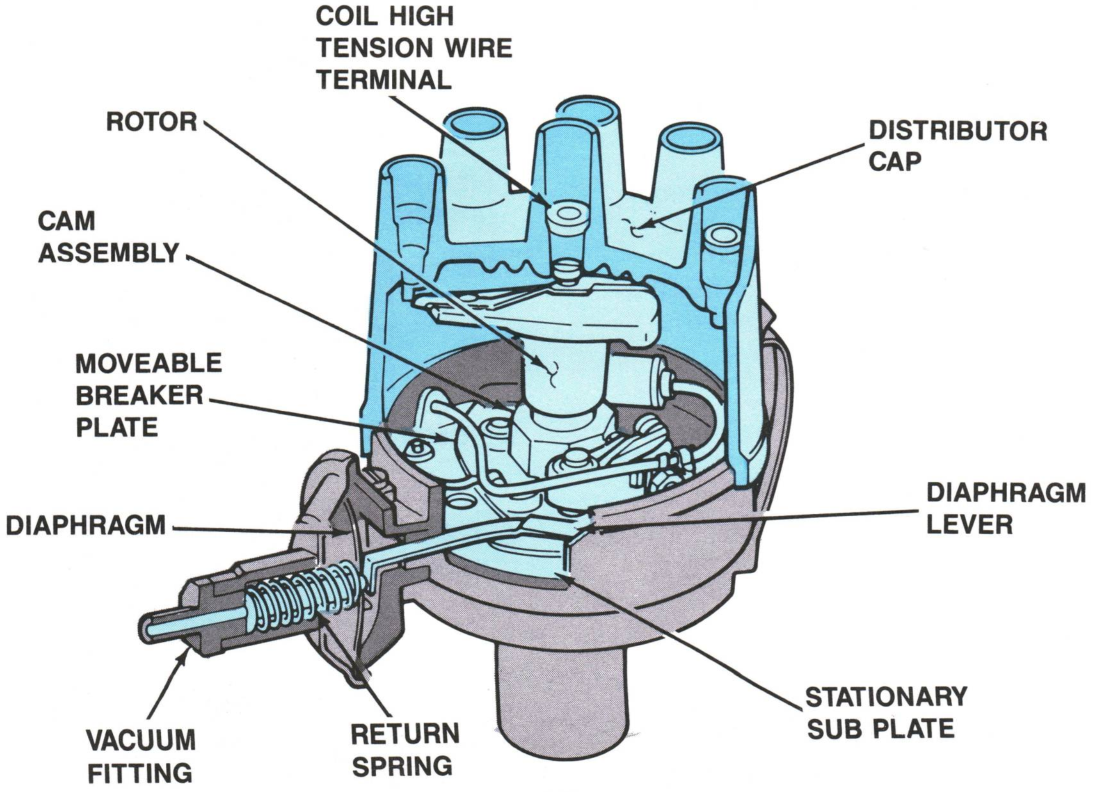
Covering the distributor assembly is the distributor cap. It has connections called cable towers, for the high tension or spark plug leads. These leads carry the high voltage produced in the secondary circuit of the coil to the distributor and then onto the spark plugs. A rotor, mounted to the distributor shaft receives the current from the coil through the cable tower in the center of the cap. As the rotor turns it directs this current to the cable towers for each of the spark plug leads, one at a time. The leads are arranged in the cap to match the firing order or the engine. Some distributor shafts turn counterclockwise while others turn in a clockwise direction. Most are deiven by the engine cam shaft through a gear and turn at half of the engine speed.

In each combustion chamber of the engine there is a spark plug. The spark plug is used to supply a gap between two electrodes. When the high voltage from the secondary coil winding is great enough to create an arc across this gap, the arc is used to ignite the fuel mixture in the combustion chamber.

OPERATION OF THE STANDARD SYSTEM

The ignition system is divided into two circuits, the primary or low voltage circuit and the secondary or high voltage circuit. The primary circuit contains the battery, ignition switch, resistor, ignition coil primary windings, ignition points and the condenser. The seconday circuit contains the coil secondary windings, high-tension leads, distributor cap, distributor rotor and the spark plugs.

The system begins to operate as the ignition switch is turned on and the engine is cranked. As the ignition points close, current flows through the primary circuit. This current flow, through the primary winding of the coil, pro-

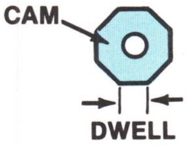


duces a strong magnetic field within the coil. As the ignition points open, current flow in the primary circuit stops, causing the magnetic field around the primary winding to collapse. The condenser aids in this collapse by furnishing a low resistance path and a current storage place during the field collapse. The magnetic lines of force around the primary winding cut through the hundreds of turns of the secondary winding and induce a high voltage in the secondary winding. This voltage can be 20,000 volts or more and can jump the gap between the distributor cap and rotor. The current flows through the rotor to one of the spark plug cable towers in the cap, through the high-tension lead to the spark plug and jumps across its gap. This high voltage causes an arc across the spark plug electrodes which ignites the fuel mixture in the combustion chamber.

When the ignition points separated and the magnetic field started to collapse, a voltage was also induced in the primary winding. This voltage can be as high as 250 volts, and can cause an arc across the face of the ignition points. The condenser is connected to the ignition points to divert the current flow from the arc. This brings the primary current to a quick controlled stop for efficient coil operation. The condenser also reduces the arc at the ignition points and in doing so prolongs the life of the points.

IGNITION POINT DWELL

Ignition point dwell is a term used to describe the time the ignition points stay closed in a standard ignition system. The proper term for dwell is dwell angle. Dwell angle describes the number of degrees the distributor cam turns while the ignition points remain closed.

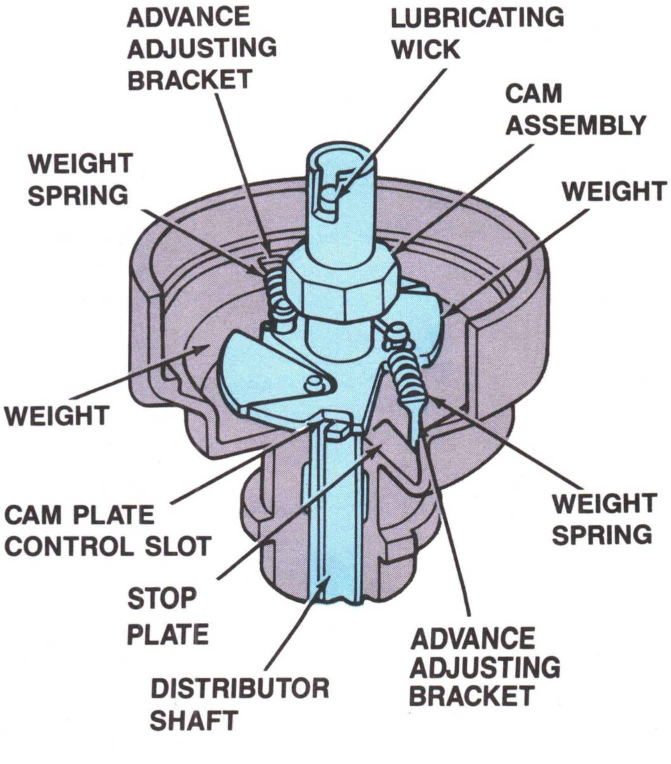


SPARK ADVANCE SYSTEMS

The distributor assembly serves three purposes. First it must control the primary circuit by opening and closing the ignition points. Second is to direct the high voltage current in the secondary circuit to the proper spark plug. The third is to time the delivery of the high voltage to meet the engine requirements of speed and load. The third function is the job of the advance systems. There are normally two systems used. They are: the centrifugal advance and the vacuum advance. Both are integral parts of the distributor assembly.

CENTRIFUGAL ADVANCE

The centrifugal advance is sometimes referred to as the mechanical advance system. It is made up of fly weights and springs and is housed in the distributor. The centrifugal advance is connected to the upper part of the distributor shaft and will advance the distributor cam based on distributor R.P.M. As the R.P.M. increases the weights move away from the distributor shaft and overcome spring tension, the higher the R.P.M. the more the weights move. The distributor shaft is made as two pieces, the lower portion is the shaft, the upper is the cam assembly. The more the weights move, the more the cam assembly is advanced. How fast it will advance is based on spring tension.



VACUUM ADVANCE SYSTEM

Distributor assemblies are equipped with a vacuum advance system for better fuel economy when the engine is operated at part throttle. The vacuum advance consists of a spring loaded diaphragm connected to the distributor plate by a link.

A hose runs from the spring side to either the intake manifold or the carburetor. Vacuum is used to overcome the spring tension and rotate the distributor plate opposite distributor cam rotation. This causes the points to open sooner in the power stroke to allow a longer burn time for the fuel mixture. When the vacuum hose is connected directly to the intake manifold there will be advance at idle. When the unit is operated by carburetor vacuum there is no advance at idle. Both systems work at part throttle and neither system works at full throttle. This is due to low manifold vacuum which cannot overcome the spring tension in the unit.

Tune up specifications list a total ignition advance, which is to be checked at a specific engine R.P.M. This is the maximum advance reached by combining both the vacuum and centrifugal advance systems.

You now should have a basic knowledge of the standard ignition system and are ready to proceed to the electronic system.

ELECTRONIC IGNITION SYSTEM

An electronic ignition system is one that does not contain ignition points. Instead the primary circuit is controlled electronically by an electronic switching unit.

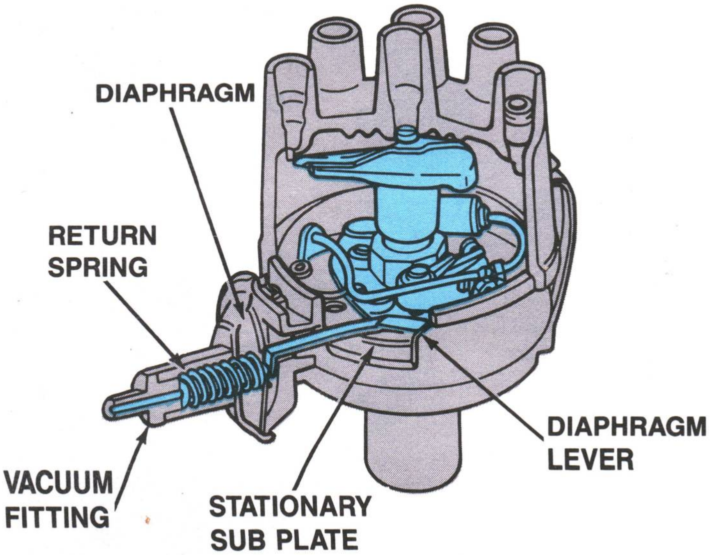
In an electronic ignition system the primary circuit contains:

- Battery
- Ignition Switch
- Primary Coil Windings
- A Magnetic Pick-Up Assembly, often called the Stator Assembly
- An Electronic Switching Unit

The battery, ignition switch, and primary coil windings operate the same as in the standard system. The magnetic pick-up replaces the moveable parts of the ignition points. They are the distributor cam, cam follower and moveable point arm. The electronic switching unit replaces the ignition point contacts and the condenser.

The secondary circuit in an electronic ignition system containing the same components as the standard ignition system. They are:

- Secondary Coil Winding
- Distributor Cap
- Distributor Rotor
- High Tension Leads
- Spark Plugs

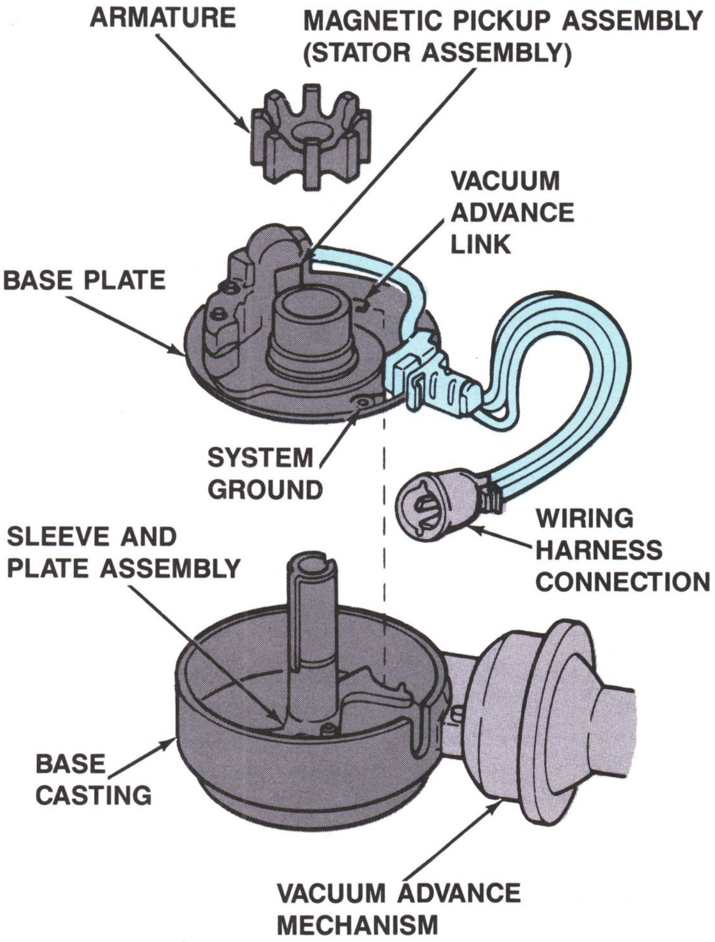


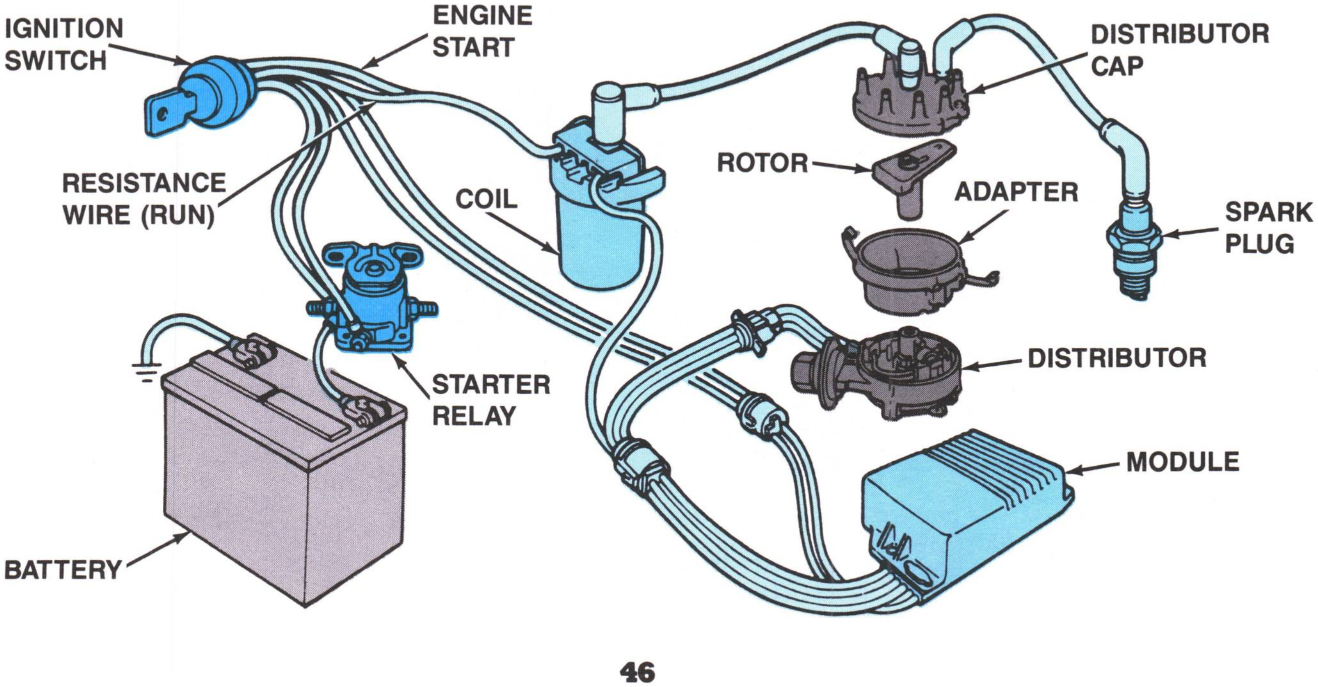
BASIC GASOLINE ENGINE

OPERATION OF ELECTRONIC IGNITION SYSTEM

Operation of the primary circuit, in an electronic ignition system, is the job of the pick-up coil and electronic switching unit. The magnetic pick-up assembly is made up of an armature, containing the same number of poles as there are cylinders in the engine, a permanent or electro magnet, and a pick-up pole. The armature makes up the upper part of the distributor shaft and replaces the cam found in this position on the standard ignition system. The pick-up coil is mounted to the distributor plate as the ignition points were in the standard system.

The magnetic pick-up assembly functions much like a self-energized alternator. As the distributor shaft rotates the poles or fingers of the armature pass in front of the pick-up coil. As the finger approaches the pick-up coil a positive voltage is induced, reaching its peak just as the two poles aline. As the armature pole moves away from the pick-up coil the negative current is produced. This cycle happens continuously as long as the distributor shaft is turning. The voltage produced by the pick-up assembly is supplied to the electronic switching unit. The unit uses this very small voltage signal to open and close the coil primary circuit just as the ignition points and condenser control the primary circuit in the standard ignition system.


ARMATURE
MAGNETIC PICKUP ASSEMBLY (STATOR ASSEMBLY)
VACUUM ADVANCE LINK
BASE PLATE
SYSTEM GROUND
SLEEVE AND PLATE ASSEMBLY
WIRING HARNESS CONNECTION
BASE CASTING
VACUUM ADVANCE MECHANISM



The balance of the electronic ignition system operation is identical to that of the standard ignition system. The electronic switching unit opens the primary circuit in the ignition coil just as the signal from the pick-up coil changes from positive to negative. The opening of the primary circuit causes its magnetic field within the ignition coil to collapse. The collapse of the field induces a high voltage in the coil secondary winding. This high voltage is then sent to the spark plugs through the high tension leads, the distributor cap and the rotor. When the high voltage reaches the spark plug, it jumps the gap between the spark plug electrodes and ignites the air fuel mixture in the combustion chamber.

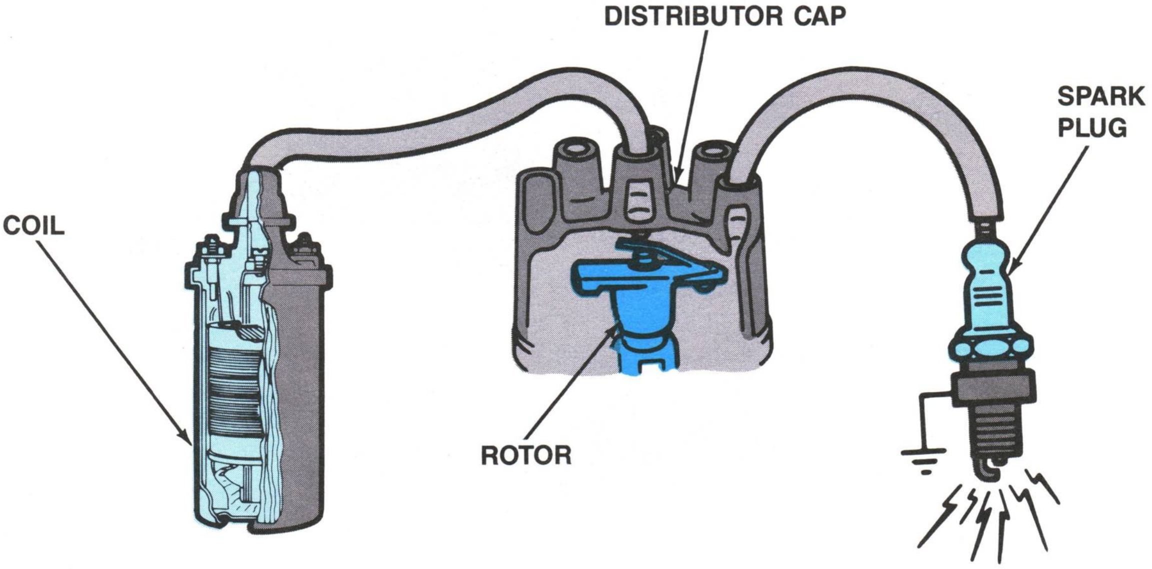
ELECTRONIC IGNITION SYSTEM DWELL

In a standard ignition system the dwell angle is set by adjusting the ignition points. It will vary as the cam follower wears and the point gap becomes smaller. The dwell angle in an electronic ignition system is controlled by the switching unit and cannot be adjusted. The dwell angle will remain proper for the life of the switching unit.

ELECTRONIC IGNITION SYSTEM ADVANTAGES

There are many advantages to electronic ignition systems as found in today's fuel efficient engines. Listed here are the more important ones:

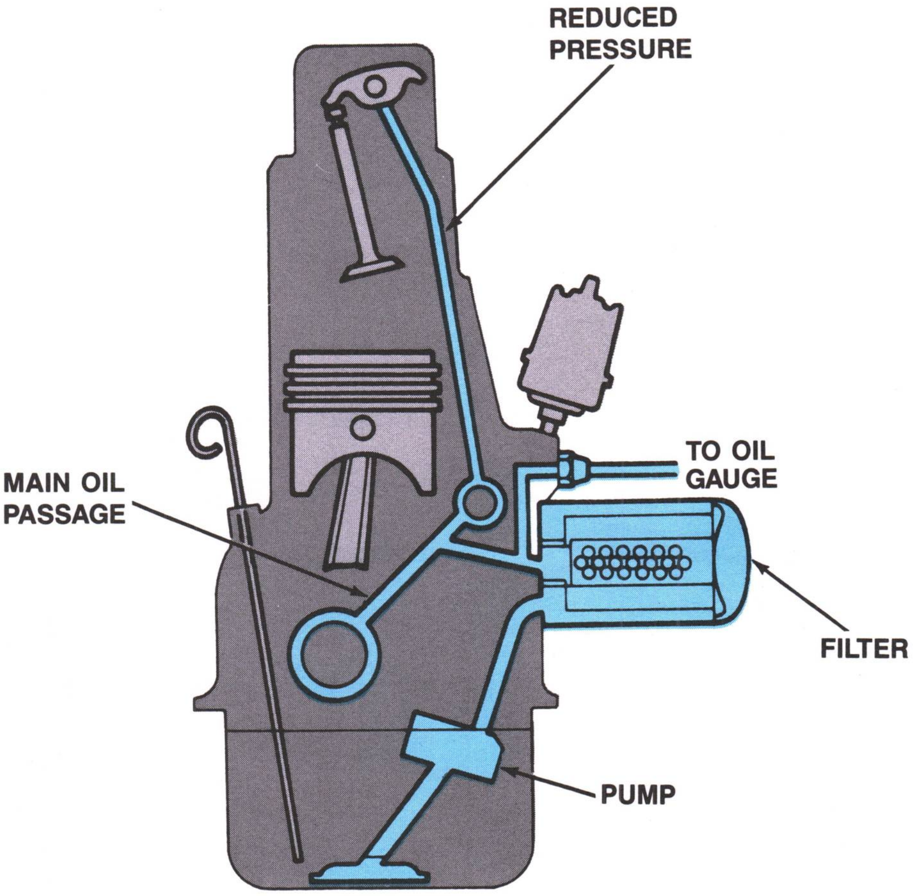
- No ignition points, which need periodic adjustment or replacement.
- Ignition timing, once set, remains correct.
- High secondary voltage. We no longer have point arcing as there are no points.
- No miss fire at high engine R.P.M. due to ignition point bounce.
- Longer spark plug life, due to higher secondary voltage.
- Easier engine starting under all conditions.
- Better fuel economy.
- Cleaner emissions.



LUBRICATION SYSTEM

An engine's lubrication system must perform several functions. First it must be able to hold an adequate supply of lubricating oil, it must be able to remove contamination from the oil and deliver it to all necessary areas of the engine. The main components of this system are the oil pan or sump, oil pump, oil pump pick-up, engine oil passages, and the oil filter. Secondary components of the system are the crankcase vent system, oil pressure indicator, oil seals and gaskets, and the dipstick. We will now look at the function of each of these components.

- Oil pump. The oil pump is the heart of the lubrication system. Just as the heart in your body circulates blood through your veins, the oil pump circulates oil through the engine.
- Oil pump pick-up. The oil pump pick-up is a line from the oil pump to the oil stored in the oil pan. It usually contains a filter screen which is submerged in the oil at all times. The screen serves to keep large particles from reaching the oil pump. This screen should be cleaned anytime the oil pan is removed.



- Oil pan or sump. The oil pan attaches to the crankcase. It serves as the reservoir for the engine's lubricating oil. It is designed to hold all the oil necessary to lubricate the engine when it is running, plus a reserve. The oil pan helps to cool the oil through its contact with the outside air.

- Engine oil passages. The oil passages are designed to carry the engine oil to all necessary areas. They are drilled or machined into the cylinder block, cylinder head, crankshaft and camshaft. In some applications these passages may be external piping added to the engine assembly to feed engine driven accessories.

- Oil filter. The engine oil filter is designed to remove minute particles of metal and dirt from the engine oil. This is necessary so they will not circulate through the engine and cause premature wear to it. Filtering also increases the useable life of the oil.

- Crankcase ventilation. Crankcase ventilation is necessary because of pressure that can build in the crankcase due to combustion pressure which passes the piston rings. Piston rings do not provide a complete positive seal of the combustion area and some combustion gases reach the oil pan. These gases can contaminate the oil and apply unwanted pressure to gaskets and seals.

- Oil pressure indicator. This system may be in the form of a gauge which indicates the engine oil pressure at all times or it may be a warning light which will come on anytime the engine is running with insufficient oil pressure. The warning light is the most common oil pressure indicator.

- Oil seals and gaskets. Oil seals and gaskets are used throughout the engine to prevent both external and internal oil loss. The most common materials used for sealing are synthetic rubber, soft plastics, fiber and cork. In critical areas these materials may be bonded to metal.

- Dipstick. The dipstick is used to measure the level of oil in the oil pan. The end of the stick is marked to indicate when the engine oil level is correct. It has a mark to indicate the need to add oil to the system.

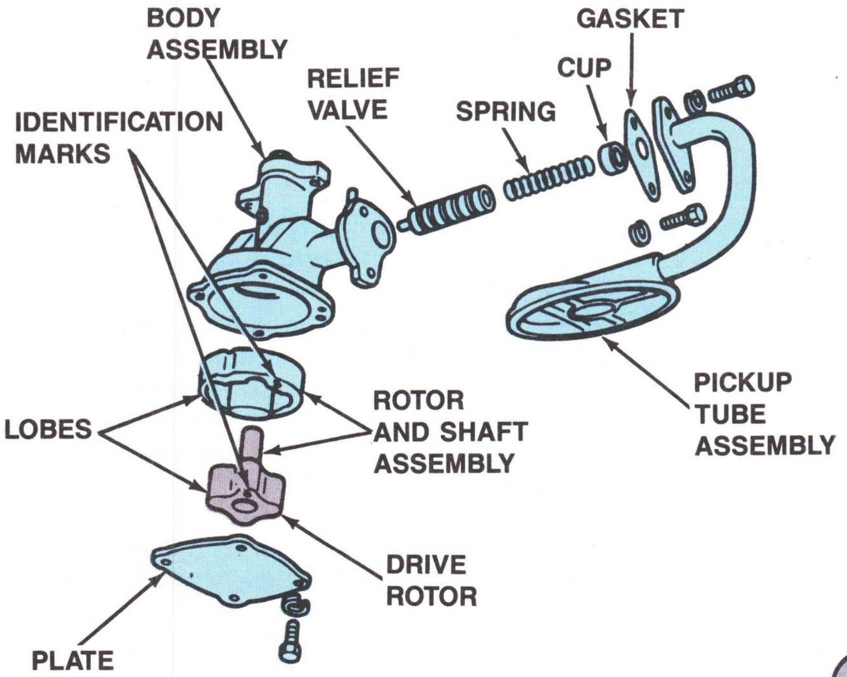
Now that we have taken a broad look at the lubrication system we will concentrate on some of the more involved components.

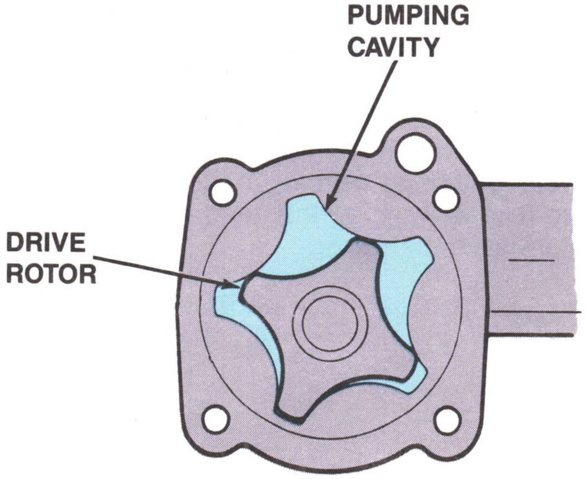
OIL PUMPS

The two most common types of oil pumps are the gear type and the rotor type. Ford oil pumps are of the rotor type. The pump is made up of a housing or body which contains a drive shaft, a male and female rotor, and a pressure relief valve. The oil pump is located in the oil pan and is driven by the distributor through the drive shaft. As the two rotors turn, pumping cavities are formed between the lobes. These pumping cavities draw oil through the oil pick-up and pressurize it by trapping the oil between the moving rotors. The oil under pressure is then sent to the oil filter. This type of oil pump is referred to as a positive displacement oil pump. Oil cannot enter the pump and recirculate inside it. What oil enters through the inlet must leave through the outlet.

With this type of pump oil pressure will be high when the oil is cold, such as cold start up, and it will become higher as the pump turns faster, such as high engine R.P.M. To keep the pump from supplying oil pressure which would be too high and damage the oil filter and seals, a pressure relief valve is incorporated into the pump housing. This relief valve is a spring type valve, when the pressure from the pump is greater than the spring pressure, it pushes the valve off its seat. Excess oil pressure passes the valve and the oil is returned to the crankcase.

The lubrication system in Ford engines operate at a pressure of 275 kPa (40 psi) to 414 kPa (60 psi). This oil under pressure passes first through the oil filter then onto the main oil gallery. From the gallery it is directed to the main bearings, the connecting rod bearings, camshaft bearings, and the hydraulic tappets. This pressure also supplies the oil sprayed on the cylinder walls through the holes in connecting rods. Reduced oil pressure is supplied to other parts of the engine. This reduction is achieved by restricting the size of the oil passage. This is necessary to eliminate engine bearing starvation, and oil consumption. The areas that receive this reduced oil pressure are the push rod ends, shaft pivoted rocker arms and some distributor shafts. The oil returning to the oil pan is also used for lubrication. Some areas receiving this non-pressure lubrication are the timing gears, sprockets, timing chain, solid tappets and cam lobes.

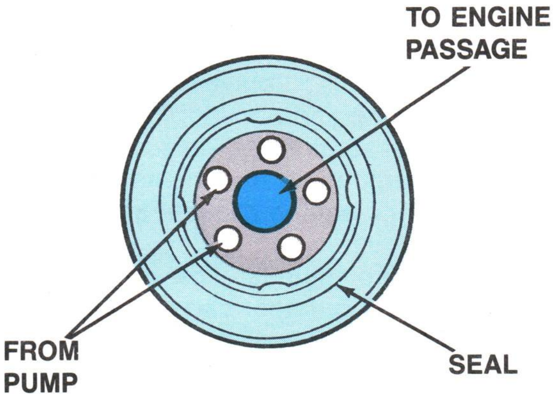




OIL FILTER

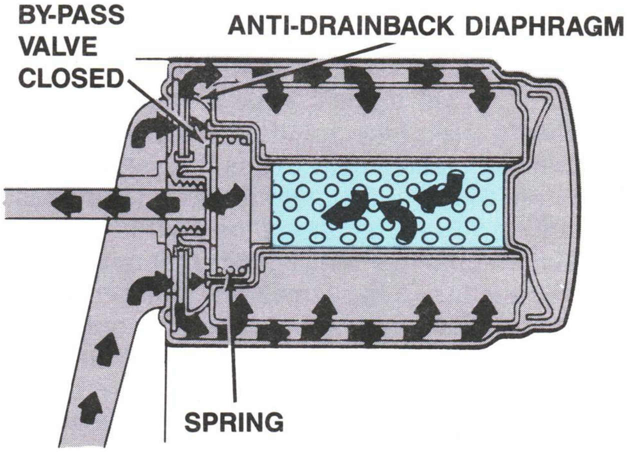
As we mentioned in the oil pump section, all oil leaving the oil pump is directed to the oil filter. The oil flows through the filter then on to lubricate the engine. This type of filtering is called full-flow. No oil reaches the engine that is not filtered. This insures that very small particles or dirt and metal carried by the oil will not reach the close fitting engine parts. The filter element and container are made as a unit, with a seal built in at the point the filter assembly contacts the block. The filter assembly threads directly on to the main oil gallery tube, eliminating external oil leaks and the possibility of oil leakage under pressure. The oil from the pump enters the filter can on the outside of the element, passes through the element to the center of the filter and into the main gallery.

FULL-FLOW FILTER



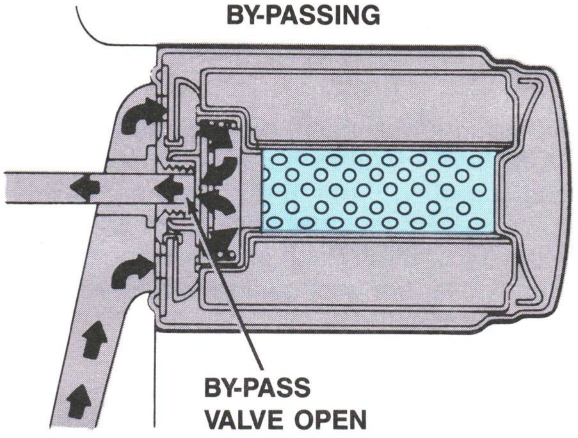
Ford filters also contain an anti-drainback diaphragm. This unit keeps the oil filter primed, or full of oil, when the engine is not running. By keeping the oil filter primed it will require less time for the oil to reach the engine bearings when the engine is restarted. The diaphragm covers all the filter inlet holes from the inside. Oil pump pressure easily moves the diaphragm to open the filter. When pump pressure stops the oil within the filter pushes the diaphragm closed trapping the oil.

FILTERING



Full flow oil filter systems have one possible drawback. If the filter is not changed at the proper time it can become blocked. The blocked element will restrict oil flow reaching the bearings and damage could occur. To overcome this drawback, Ford filters have a built-in bypass valve. Should the element become blocked, oil pressure will build at the filter inlet. This increase in pressure will open the valve and the oil can flow unfiltered to lubricate the engine. At this point, unfiltered oil is better than no oil at all. Replacing the filter will return the system to its normal operation.

BY-PASSING



BASIC GASOLINE ENGINE

CRANKCASE VENTILATION

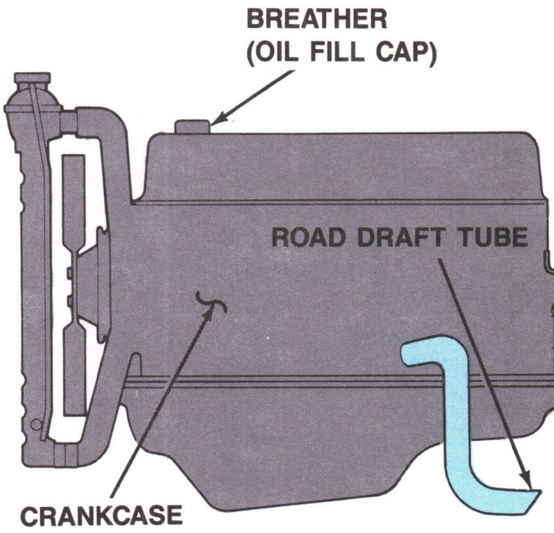
The crankcase ventilation system is considered part of the engine lubrication system because one of its functions is to prevent blow by gases from contaminating and breaking down the engine oil. The system is also used to prevent pressure from building in the engine which would damage the engine gaskets and seals.

On earlier gasoline engines, blow by gases were vented through the breather cap and a road draft tube. A road draft tube is simply a pipe used to carry the gases to the atmosphere. This system works well but adds to air pollution, it also has the tendency to drip oil.

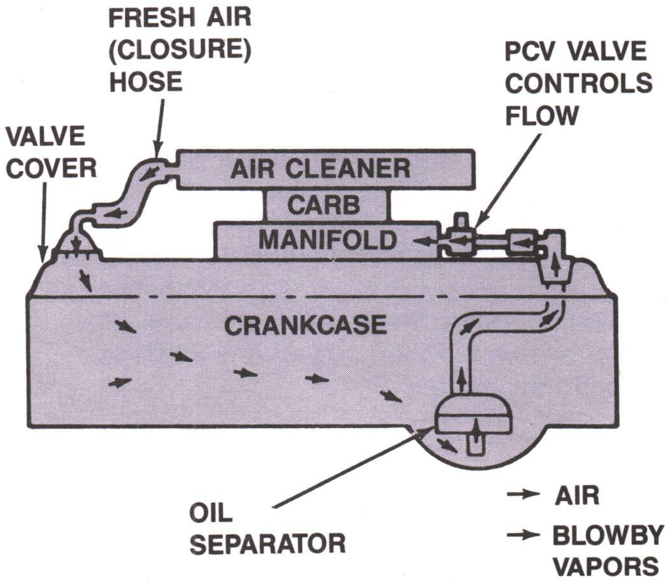
To meet emission standards the positive crankcase ventilation system is fitted to most, if not all automobile engines. This system is called the P.C.V. system. The system contains a sealed oil cap, with a hose that leads to the air filter, a P.C.V. valve and a hose which runs from the valve to the intake manifold. As pressure builds in the crankcase it opens the valve. Vacuum in the intake manifold draws the fumes through the valve. The fumes then enter the combustion chamber with the air fuel mixture and are burned. As the fumes are removed they must be replaced by fresh air. If this is not done a vacuum will develop in the crankcase which would draw the oil from it. The fresh air is drawn from the air filter through the oil filler cap and the air cleaner. The P.C.V. valve serves to regulate the flow of crankcase fumes and acts as a safety valve. Should the engine backfire, the pressure in the intake manifold will close the valve keeping the backfire from reaching the crankcase.

The fuel induction systems on engines equipped with P.C.V. systems are set up to compensate for the air supplied through the system. For this reason the system must be kept clean and the proper valve installed. Each engine type requires a different valve, the wrong valve will affect engine performance.

We have now seen the components of the lubrication system, where the oil is stored, how it is pressurized, where it goes to and what it does. We will now look at the lubricating oil itself.



OLD ROAD DRAFT METHOD

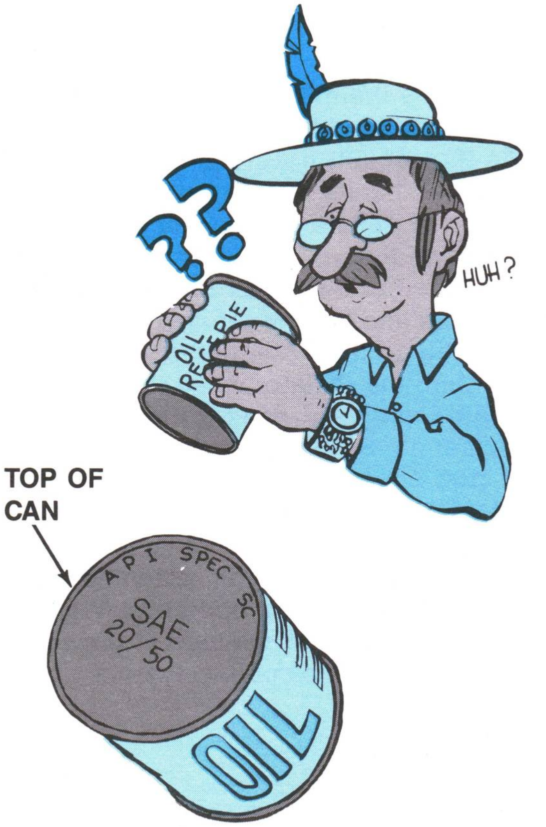


P.C.V. SYSTEM

LUBRICATION INFORMATION

It is very important that you understand all oil is not created equal. The top of the oil can or container will tell you two important things. First the viscosity of the oil, second the design use for the oil. The S.A.E. ratings tell you the oil's viscosity while the A.P.I. designation tells you the oil's intended use.

First we will look at the S.A.E. viscosity rating. What is viscosity? Viscosity is an expression of the internal friction of a fluid, and is one of the



most important properties of lubricating oils. What is S.A.E.? The Society of Automotive Engineers is called the S.A.E. The S.A.E. viscosity number system is used worldwide to designate the degree of viscosity of engine and transmission oils. The viscosity characteristic curve distinguishes the viscosity temperature behavior of a lubricating oil. In simple terms the S.A.E. numbers will tell you the temperature range that the oil will lubricate best. An S.A.E. 10 will lubricate well at low temperatures but will become too thin and breakdown at high temperatures. S.A.E. 30 will lubricate well at mid temperatures but become too thick at low temperatures to supply good lubrication. Multigrade oils are engine oils which cover more than one S.A.E. viscosity number. Their short designations are made up from the designations of the two viscosity numbers that the oil has met. For example an S.A.E. 10W30 oil meets the requirements of a 10 weight oil for cold start and cold lubrication, and the requirements of a 30 weight oil for mid temperature lubrication.

Most automobile manufacturers recommend a multigrade oil for their engines, as this insures good lubrication over a wider temperature range. Now we will look at A.P.I. service designations. First what is the A.P.I.? A.P.I. stands for the American Petroleum Institute. A.P.I. service designations are used in the United States to determine the engine service qualifications of engine oils. These qualifications are indicated by the letters found on the containers.

A.P.I. DESIGNATION

SC — Service typical of gasoline engines in 1964 through 1967. Oil designed for this service provides control of high and low temperature deposits, wear, dust and corrosion in gasoline engines.

SD — Service typical of gasoline engines in 1968 through 1970. Oils designed for this service provide more protection against high and low temperature engine deposits, wear, rust and corrosion in gasoline engines. SD oil may be used in engines requiring SC oil.

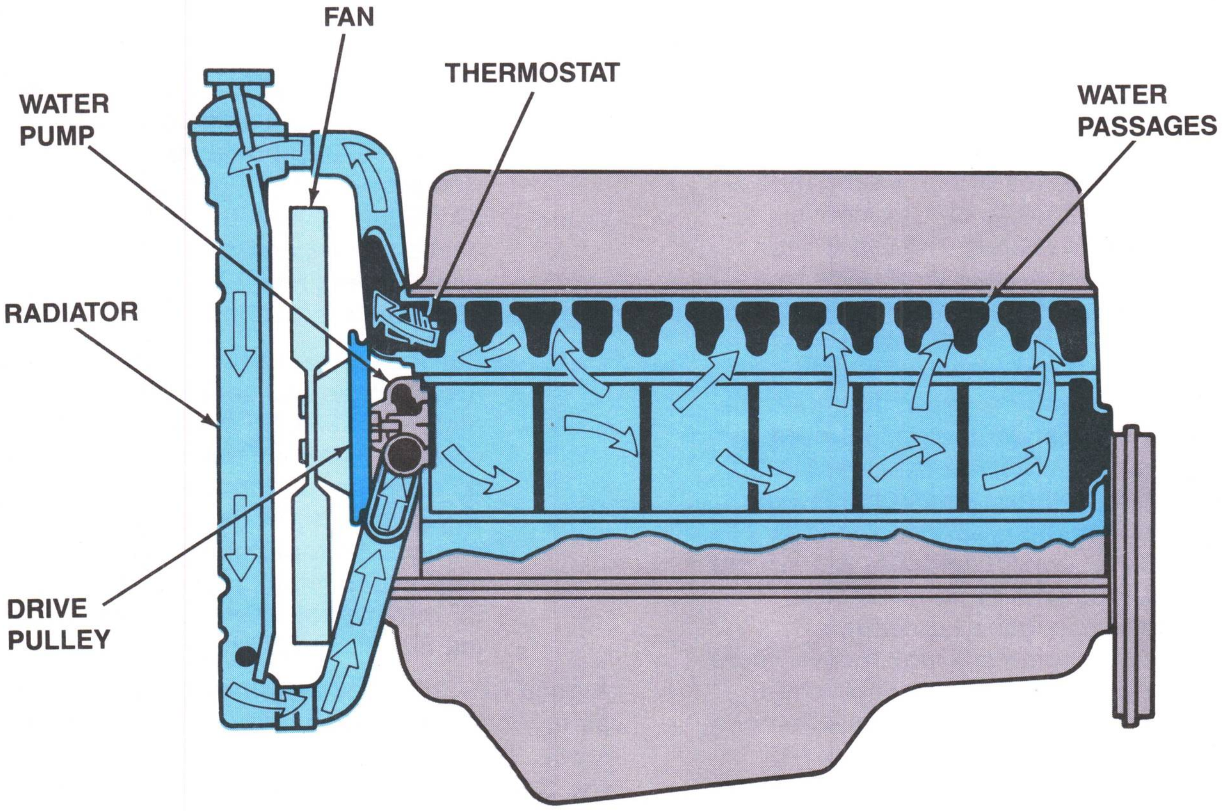
SE — Service typical of gasoline engines in automobiles and some trucks beginning in 1972. Oil designed for this service provides more protection against oil oxidation, high temperature engine deposits, rust and corrosion in gasoline engines. SE oil may be used in engines requiring SC or SD oil.

SF — Service typical of gasoline engines in automobiles and some trucks beginning with 1980. SF oils provide increased oxidation stability and improved anti-wear performance over oils which meet A.P.I. designation SE. It also provides protection against engine deposits, rust and corrosion. SF oils may be used in engines requiring SC, SD or SE oils.

A good rule for A.P.I. designations is you may go higher than required, but you should not go lower. You will also find A.P.I. designations CA, CB, CC and CD. These are for diesel engines. If the A.P.I. designation your automobile requires appears on the container, the oil will meet the needs.

COOLING SYSTEM

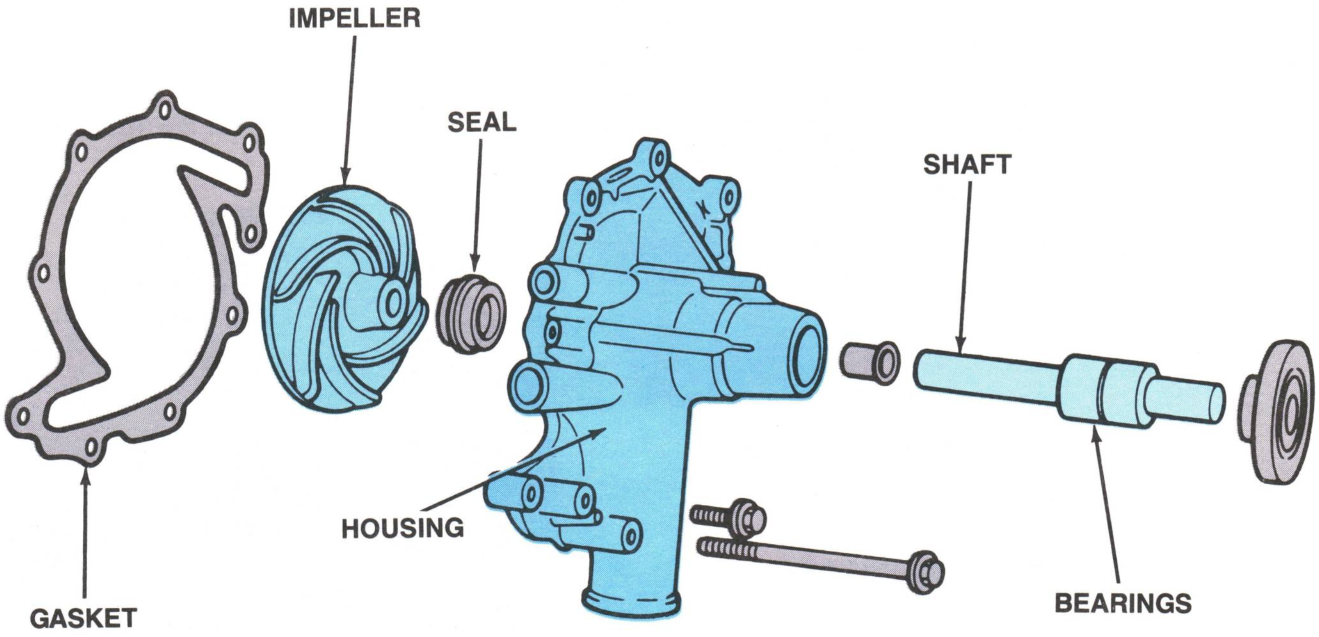
The parts of the cooling system are: the radiator,coolant recovery system, radiator pressure cap, the water pump and fan, the thermostat and the hoses which connect the parts of the system together. The water pump is belt driven by the engine crankshaft. The engine cooling fan may be mounted on the water pump or operated electrically. Coolant is pumped or circulated by the water pump from the bottom or side of the radiator through internal passages in the engine block and heads. The internal passages are often called the water jacket. The water pump then pumps the coolant through the thermostat to the top tank of the radiator. From the top tank the coolant flows slowly through a system of tiny tubes surrounded by cooling fins. These tubes and fins are called the radiator core. When the coolant reaches the opposite radiator tank the process begins again. Actually from the point the thermostat opens, the coolant is constantly circulated through the engine and radiator. As the coolant travels through the engine block and heads, unwanted heat caused by combustion is transferred to the coolant. As the coolant flows through the radiator core this heat is transferred to the air as the air passes through the core and around the fins. The fan, usually mounted on the water pump, is used to move air through the radiator when the engine is idling or operating slowly, as in traffic. This insures sufficient air movement and good heat transfer at slow speeds. The cooling system's job is two-fold. One as we have seen, it carries away unwanted heat from the engine, it must also be able to maintain the engine temperature at the right point for efficient operation. We will explain how this is done as we look at the components that make up the cooling system.



We will begin with the water pump, as it is the heart of the system. Engine water pumps are generally impeller type. An impeller is something that is designed to push, drive or move something, in this case engine coolant. The impeller or a water pump is mounted on a shaft and designed like a rotating paddle. The shaft is mounted in the water pump housing and rotates on bearings. The pump contains a seal to keep the coolant from passing through it. At the drive end, the exposed end, a pulley is mounted to accept the belt which is driven by the crankshaft. The pump housing usually contains the mounting point for the lower radiator hose.

When the engine is started, the crankshaft turns the water pump. The pump impeller pushes the water from its pumping cavity into the engine block. When the engine is cold the thermostat will be closed. This stops the coolant from reaching the top of the radiator. In order for the water pump to circulate the coolant through the engine during warm up, a bypass passage is added below the thermostat which leads back to the water pump. This passage must be kept free to eliminate hot spots in the engine during warm up. It also allows the hot coolant to pass the valve which will open the thermostat.

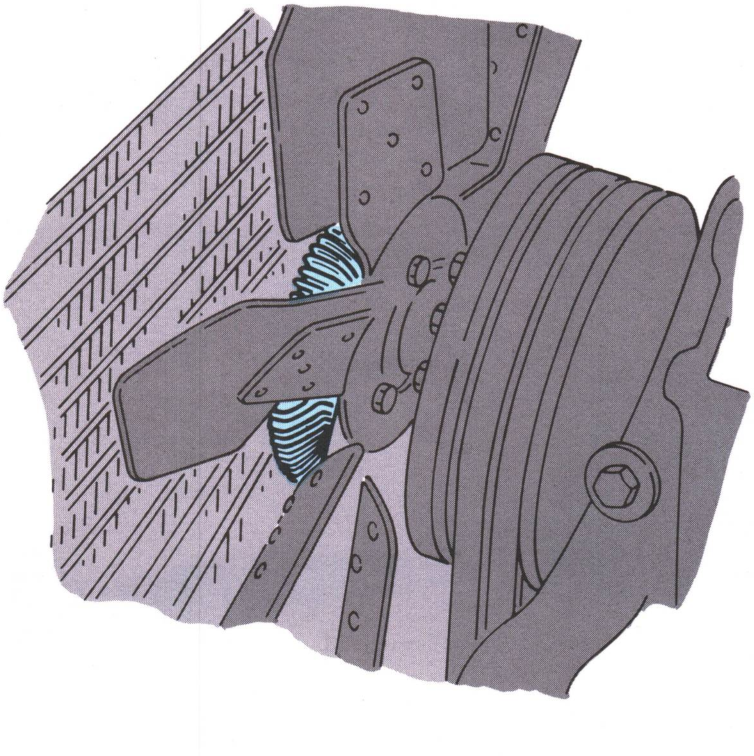
Attached to the water pump at its drive pulley is the cooling or engine fan. The fan is driven or turned at approximately crankshaft speed. It is used to move air through the radiator at idle or low speed and has very little effect at high speed. Most modern fans will have four or more blades to supply good air movement. On many engines a fan shroud is used. The fan shroud is attached to the radiator and surrounds the fan. This concentrates the air flow to add to the system's cooling efficiency. Fan shrouds are found on most automobiles equipped with air conditioning.



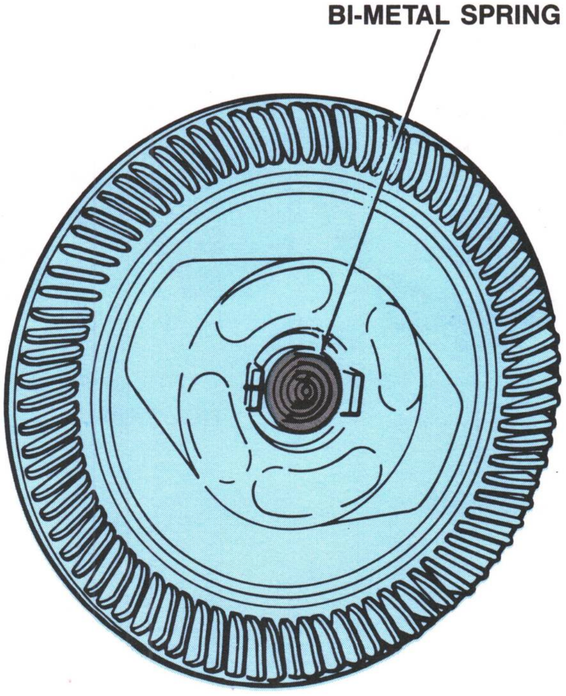
On older automobiles the fan was direct drive. It always turned at or near engine speed. As we have mentioned the fan is of little value at high speeds and it does use horsepower. To add to the engine's efficiency through a less horsepower loss, many modern engines are equipped with a viscous fan hub or drive clutch. This unit is mounted between the fan and water pump pulley. It will allow the fan to turn at engine speed when idling or low speed, but turn far below engine speed at high engine R.P.M. This also reduces the fan noise at high speed.

The viscous drive is a type of fluid coupling. The term "viscous" refers to the viscosity or thickness of the fluid in the drive. This fluid applies a form of hydraulic lock between the fan and drive pulley at low engine R.P.M. The viscosity of the fluid, combined with a bi-metal thermostat will determine the R.P.M. at which the fan will no longer keep up with engine R.P.M. The thermostat responds to air temperature and moves a piston or valve which controls the amount of fluid available to form the hydraulic lock.

Another method of conserving horsepower at high R.P.M. is the flex-blade fan. A flex-blade fan tends to flatten or lose pitch as its speed increases. The flatter the fan becomes, the less the drag. Less fan drag allows a greater horsepower saving at road speed.



FAN DRIVE CLUTCH



As mentioned earlier the cooling system must dispose of unwanted engine heat. It must also be able to maintain the engine temperature at an efficient operating level.

Modern automobile engines, driven at high speeds, generate enough heat to melt the average engine block in less than half an hour. Combustion chamber temperatures can reach as high as 2480ºC (4500ºF). This heat can cause exhaust valve heads to become cherry red, burn pistons and rings, and warp cylinder heads.

High temperatures are even more critical with the addition of emission control systems. Emission control systems cause engines to run even hotter.

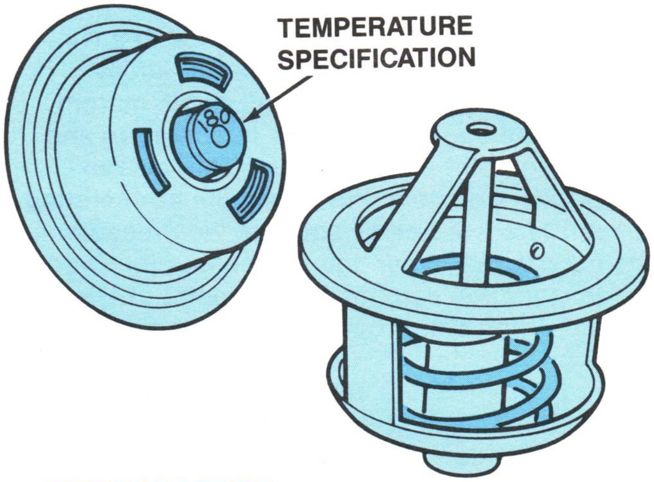
On the other hand, if an engine runs too cool, equally serious problems can occur. Engine performance will drop, emissions will soar, and engine life can be shortened due to crankcase sludging and oil contamination.

In your home the thermostat on the wall senses the temperature and operates your heater or air conditioning unit to maintain a comfortable temperature. In an automobile engine the thermostat senses coolant temperature. It will either open or close to keep the engine at a comfortable temperature.

The cooling system thermostat is nothing more than a valve that is controlled by heat. It is operated by a wax capsule or pellet. The wax will expand and contract based on temperature. As the wax expands it will open a sleeve type valve and allow coolant to flow through the radiator. Should the engine cool down the wax contracts and the valve begins to close restricting coolant flow.

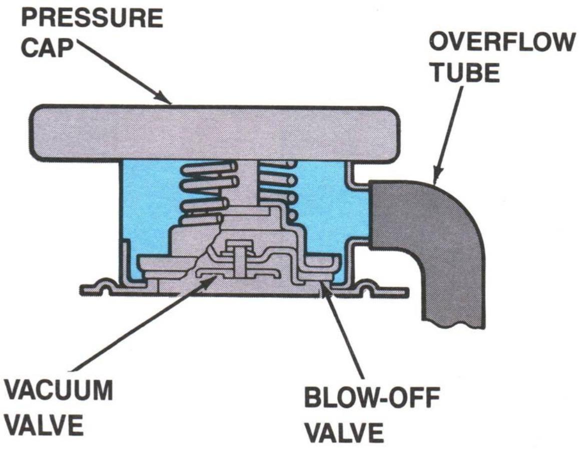
Thermostats are pre-set to begin opening at a specific temperature. The rating, or temperature that the thermostat begins to open, is stamped on the unit. A thermostat marked 82ºC (180ºF) will begin to open between 80ºC (177ºF) and 84ºC (182ºF) and will be fully opened at about 94ºC (200ºF).

Each engine requires a thermostat with a specific rating. Always install the unit that is specified to insure that the engine runs comfortably and efficiently. Never operate the engine without a thermostat. Even in its full open position it restricts or slows coolant flow through the engine block. This is necessary to eliminate hot spots and to insure that the coolant remains in the block long enough to absorb the unwanted heat from combustion.



THERMOSTAT

Today's modern engines operate at temperatures in the range of 94ºC (200ºF) and higher for peak efficiency. As we know water will boil at 100ºC (212ºF) at sea level. Using a 50/50 mixture of antifreeze and water will raise this some, but the engine temperature will still be very close to the boiling point. In order to



raise the boiling point to a safe level it is necessary to pressurize the cooling system. This is the function of the radiator pressure cap. If we install a pressure cap rated at 100 kPa (14.7 psi) we will raise the boiling point to about 125°C (257°F). This adds a comfortable margin between the engine operating temperature and the boiling point of the coolant. This also explains why the coolant in an engine at operating temperature will boil as soon as the pressure cap is removed. When the pressure is removed, by removing the cap, the boiling point of the coolant drops below operating temperature.

The radiator pressure cap is fitted to the radiator filler neck. It is used to seal the radiator. The cap has two valves built into it. One called a blow off valve, the other called a vacuum valve. Both valves are spring loaded to their closed positions.

Should the pressure in the cooling system go above the cap rating, the blow off valve will open and vent the pressure through the overflow tube. In some cases the overflow tube leads to the ground and any coolant passing through the tube is lost. On many automobiles the overflow tube connects to a coolant recovery tank. This system will be explained in the radiator portion of this manual.

As the coolant is heated it expands, as it cools it condenses. The condensing coolant may cause a vacuum to form in the radiator. Should this happen the vacuum valve will open allowing air to enter the radiator.

Because of these two valves the pressure cap will protect the cooling system from leaks caused by too much pressure or vacuum.

In order for this system to work, the cooling system must be perfectly sealed and the proper cap must be installed.

Next we will examine the radiator. The radiator is the largest portion of the cooling system. All heat transferred from the coolant to the surrounding air takes place at the radiator.

The radiator is made up of a supporting shell, two radiator tanks and the radiator core. There are three types of radiators found in automobiles, all contain the same components.

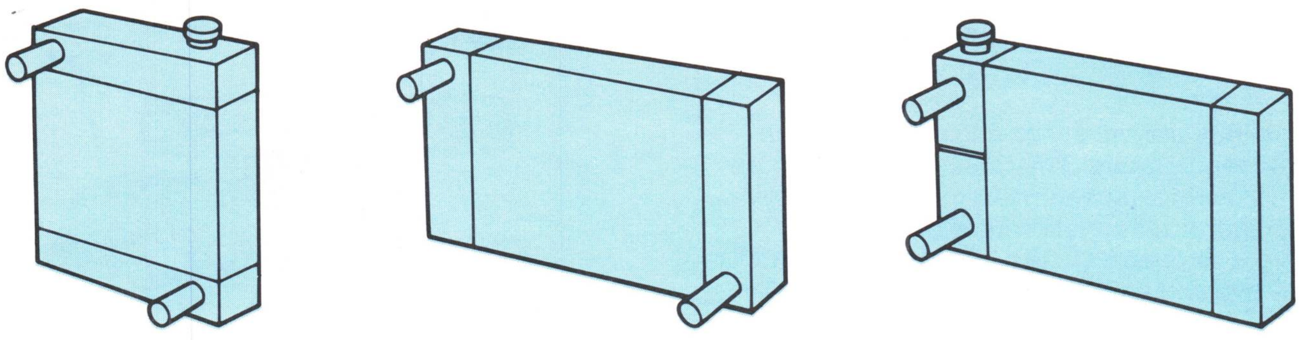
The radiator shell is used to hold the tanks and core and is the mounting point for the radiator.

The tanks are storage areas and contain the radiator hose connections and radiator filler neck.

The radiator core is the heat transfer section. It is made up of a number of small tubes surrounded by fins. The number of tubes and size of the fin area will match the cooling needs of the engine.

The three types of radiators found in today's automobiles are the conventional down flow radiator, the cross flow radiator and the double cross flow radiator.

RADIATOR TYPES



DOWNFLOW RADIATOR

CROSSFLOW RADIATOR

DOUBLE CROSSFLOW RADIATOR

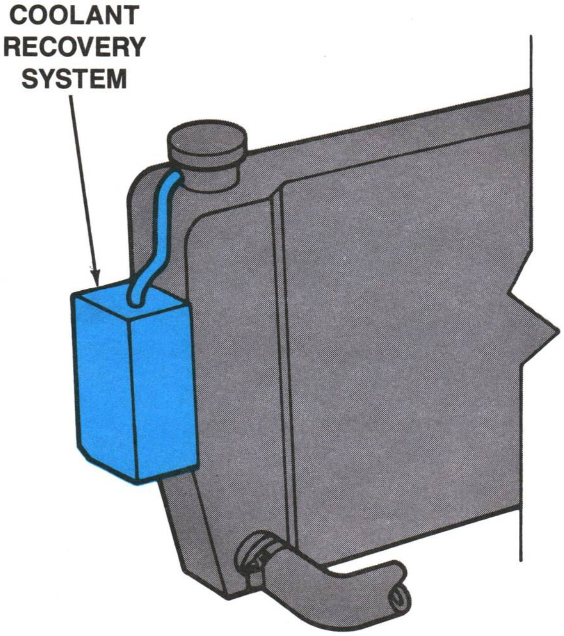
The conventional down flow radiator has its tanks positioned at the top and bottom of the core. The upper hose connects to the top tank with the lower hose at the bottom tank. The coolant enters the top tank and simply flows to the bottom. This type of radiator is usually found in vehicles where space is not a problem.

The most widely used type of radiator is the cross flow type. This radiator has its tanks on either side of the radiator core. One radiator hose will connect to each tank and the filler neck will be part of the tank used for the upper hose. The small tubes and fins run from side to side rather than up and down as in the conventional radiator. Coolant enters the radiator through the upper hose, travels across the core to the opposite tank and back to the engine through the lower radiator hose.

In some special applications where space is limited and extra coolant time in the radiator core is necessary, a double crossflow radiator may be used. The double crossflow radiator appears much like the crossflow type. The tanks are on either side of the radiator core, with the small tubes and fins running from side to side. On this type of radiator, both hose connections and the filler neck are all located in the same radiator tank. This tank is divided into an upper and lower chamber. Coolant enters the upper chamber from the upper radiator hose, it passes through the small tubes attached to the upper chamber and on to the opposite radiator tank. It will then travel back through the core by means of the tubes connected to the lower chamber of the main tank in order to reach the engine. The coolant has now been exposed to the air during two passes through the core rather than one as in the conventional or crossflow type radiators.

A vapor recovery or constant full reservoir may be installed with any type of radiator. The reservoir is connected to the overflow hose. Should the coolant in the radiator expand and open the blow off valve, the coolant will be collected in the reservoir rather than being lost. As the system cools and the vacuum valve opens the coolant will be drawn back into the radiator. This type system insures that the cooling system will remain completely full. Use of this system generally requires a special radiator cap.

Some automobiles may be equipped with a semiclosed cooling system. With this type of system the coolant level is checked and coolant is added at a non-pressurized translucent, plastic reservoir. Semiclosed systems are plainly identified by a warning decal or label attached to the radiator or cap. This warning cautions against removal of the cap except to test the coolant for freeze protection, or when draining the system for a complete coolant change. Normal checking and servicing is performed at the underhood reservoir.

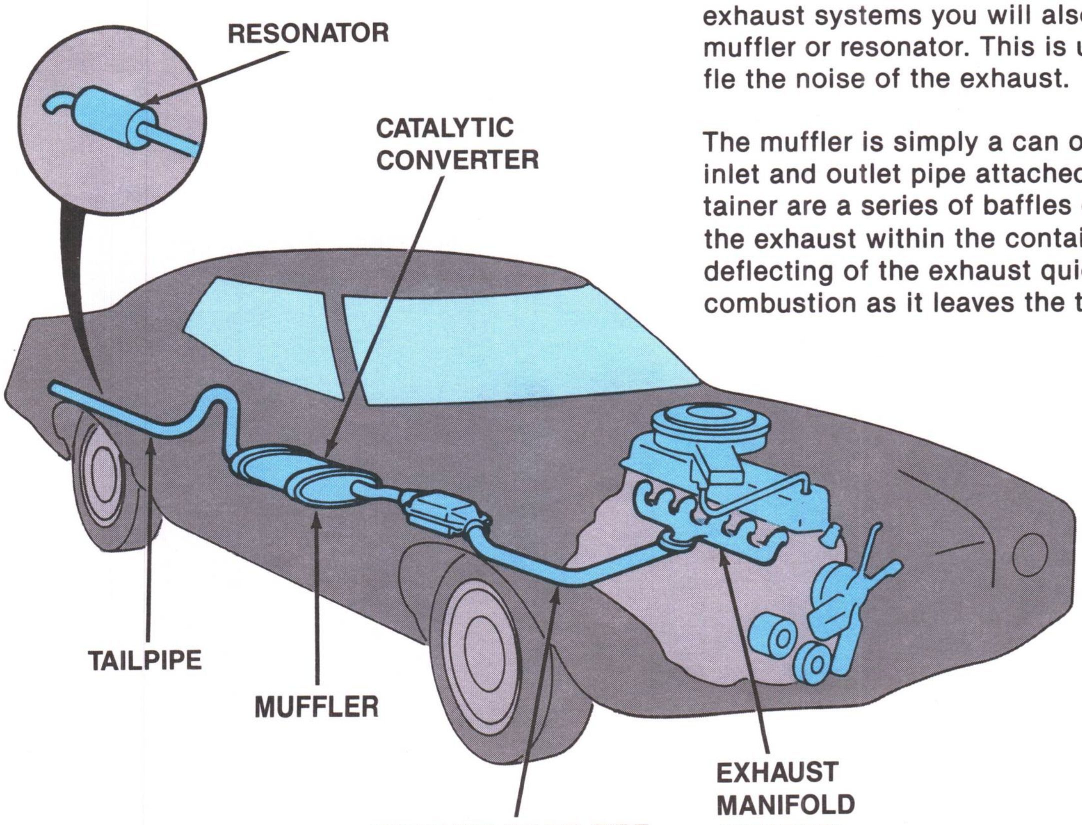


EXHAUST SYSTEM

The exhaust system is used to collect and discharge the exhaust gases caused by the combustion of the air fuel mixture within the engine. The exhaust system found on today's automobile must also aid in the control of exhaust emissions.

The engine exhaust consists mainly of Nitrogen (N_2). In addition it also contains Carbon Monoxide (CO), Carbon Dioxide (CO_2), Water Vapor (H_2O), Oxygen (O_2) Nitrogen Oxides (NOx) and Hydrogen (H_2). Also found are unburned Hydrocarbons (HC). Three of these exhaust components, CO, NOx, and HC are major air pollutants. The emission of these components to the atmosphere must be controlled.

The catalytic converter, mounted in the exhaust system, plays a major role in the emission control system. The converter works as a gas reactor, and its catalytic function is to speed up the heat producing chemical reaction between the exhaust gas components in order to reduce the air pollutants in the exhaust.



The collection of the exhaust gas begins in the exhaust manifold or header. This is the first part of the exhaust system and bolts directly to the cylinder head. The exhaust manifold is designed so that it will mate correctly with the exhaust ports of the cylinder head. All inline engines are equipped with a single exhaust manifold. While V design engines have one manifold for each cylinder head. In older automobiles it was common for a V design engine to be equipped with a complete dual exhaust system. Each side of the engine had its own system to collect and discharge exhaust. On today's automobiles the two exhaust manifolds are connected together by the exhaust or inlet pipe, which is manufactured in the form of a "Y." All exhaust gas is then discharged through a single muffler, tail pipe arrangement.

In all types of engines the exhaust gas flows from the manifold to the exhaust or inlet pipe. The inlet pipe then connects to a series of exhaust pieces made up of a catalytic converter, muffler and interconnecting pipes.

The function of the muffler is to help quiet the sound of combustion. On some large engine exhaust systems you will also find a second muffler or resonator. This is used to further muffle the noise of the exhaust.

The muffler is simply a can or container, with an inlet and outlet pipe attached. Inside the container are a series of baffles designed to deflect the exhaust within the container. The baffeling or deflecting of the exhaust quiets the sound of combustion as it leaves the tailpipe.

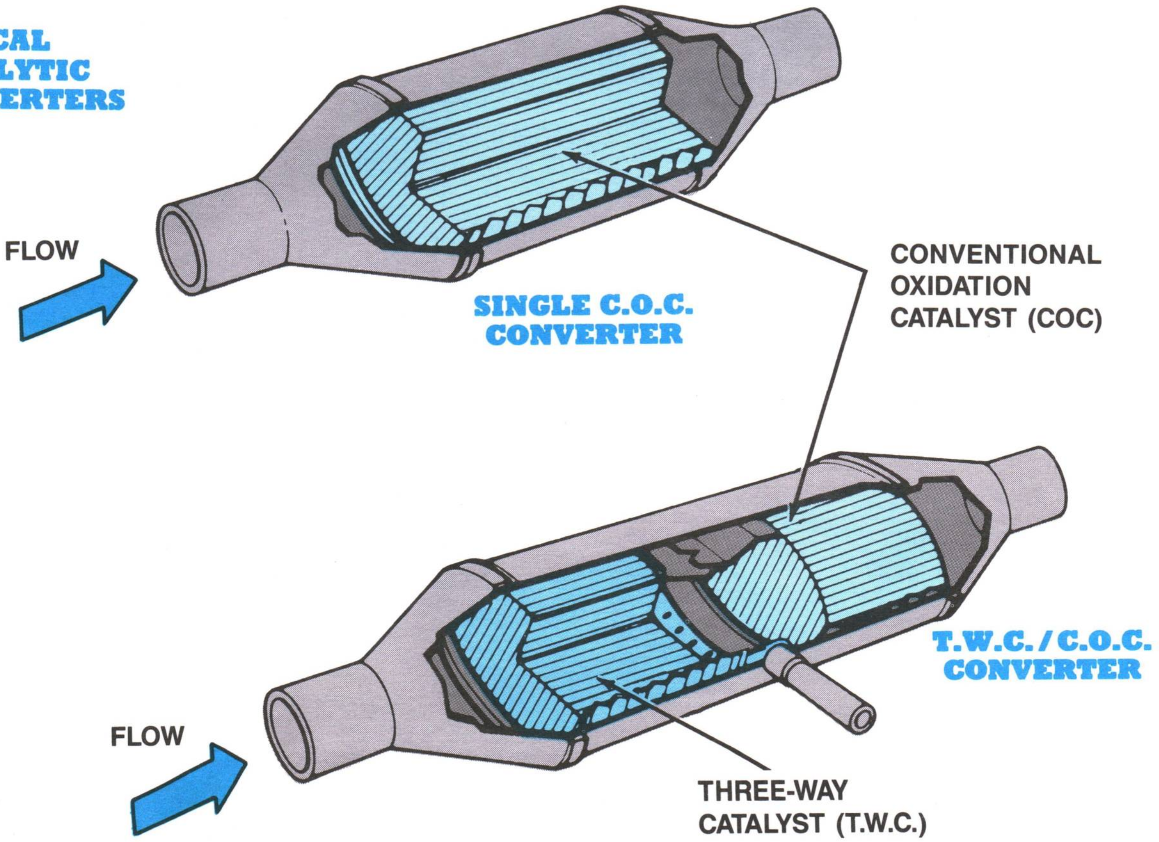
Ford exhaust systems are now equipped with a catalytic converter. A catalyst is a substance that causes a chemical change when added to something but is not changed itself. Depending on the system you will find one to four converters used. All will be of two basic types. The two types are the conventional oxidation catalyst, (C.O.C.) and a dual converter (T.W.C./C.O.C.)

The "Conventional Oxidation Catalyst" is a ceramic honeycomb coated with a catalytic material to control the emissions of hydrocarbons (HC) and Carbon Monoxide (CO). The catalytic material for the C.O.C. is platinum and palladiu. Because this unit controls only two of the three exhaust emissions it is sometimes called a two way catalyst.

The dual converter uses both the two and three way catalyst and controls oxides of nitrogen (NOx) as well as hydrocarbons (HC) and carbon monoxide (CO).

The converter contains two separate ceramic honeycombs, each coated with a different catalytic material. The front catalyst is coated with a rhodium and platinum catalyst designed to control NOx, HC and CO. This unit is commonly called a three way catalyst, as it acts on all three exhaust emissions. From the three way catalyst the exhaust gases pass through an air chamber and onto the C.O.C. converter. Air for this chamber is supplied by the thermactor pump and is necessary for proper oxidation of HC and CO in the C.O.C. converter, during cold start, warm up and full throttle operation. The rear catalyst is the "conventional oxidation catalyst" or two way catalyst. The operation of the rear section and its construction is the same as the standard C.O.C. converter. This section will further reduce HC and CO to harmless water vapor.

TYPICAL CATALYTIC CONVERTERS

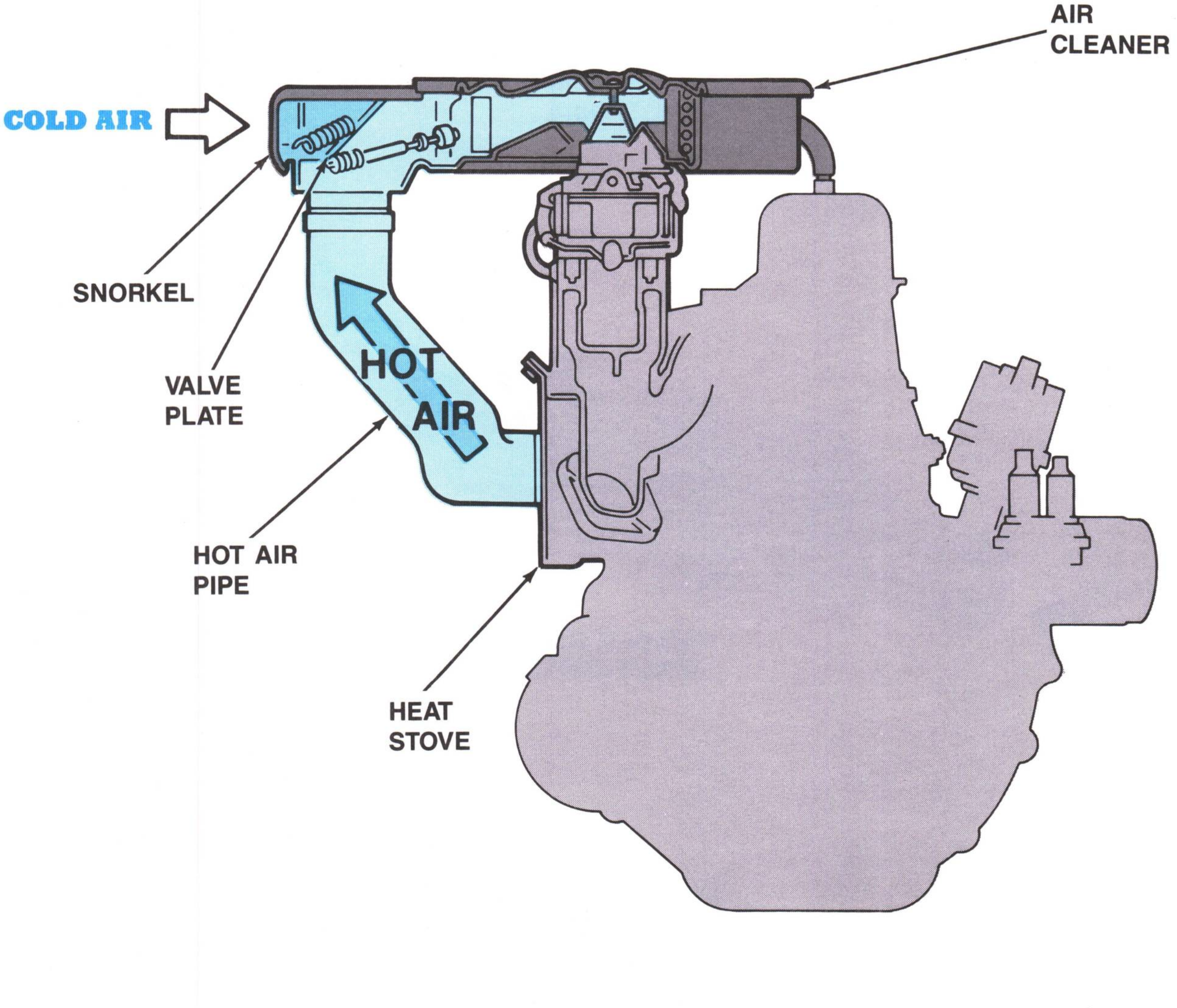

FLOW
SINGLE C.O.C. CONVERTER
CONVENTIONAL OXIDATION CATALYST (COC)
T.W.C./C.O.C. CONVERTER
FLOW
THREE-WAY CATALYST (T.W.C.)

AIR INTAKE SYSTEM

All exhaust system passages must be large enough to permit the exhaust gas to flow freely, but maintain a carefully controlled back-pressure necessary to prevent afterburn in the exhaust system. All exhaust system connections must be tight as this assures that sound deadening will be achieved. The exhaust system must also keep the exhaust gases, which can be poisonous, from reaching the passenger compartment.

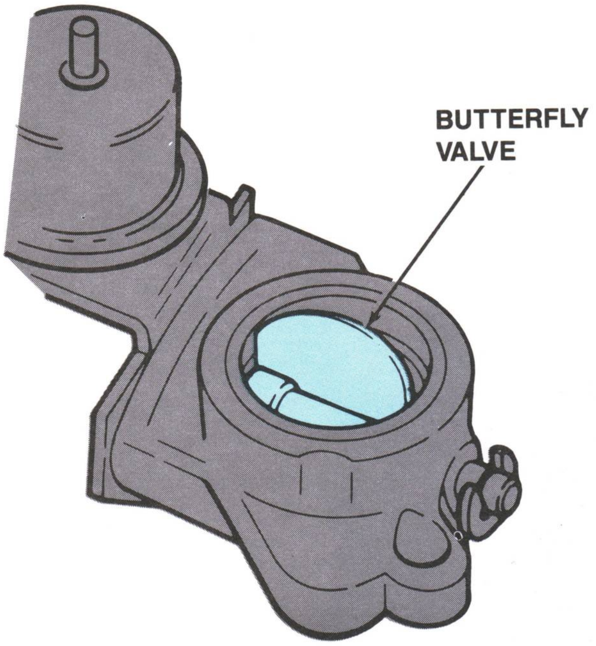
There are two additional exhaust system functions used on some automobiles, involving exhaust heat transfer to the fuel delivery system.

On modern engines the exhaust manifold is used as a stove to heat some of the air taken into the carburetor air cleaner.



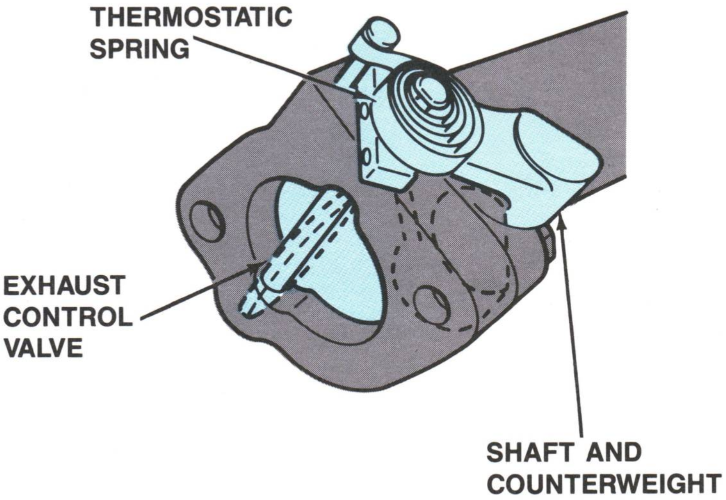
A hot air pipe or hose leads up from the manifold to the air cleaner snorkel and carries heated air to mix with normal intake air. This system is controlled by a temperature sensor in the air cleaner housing. This sensor controls the operation of a vacuum motor located at the air cleaner snorkel. When the unit is cold, vacuum is applied to the motor opening the door. Heated air from the exhaust manifold is directed to the air cleaner. As the system warms up the door is gradually closed and all air enters the air cleaner unheated. This system is used to aid in emission controls.

Some engines may use manifold heat to warm a section of the intake manifold by directing some of the exhaust gas through it. This is done through a butterfly type "heat rizer" or exhaust control valve located between the exhaust pipe and manifold. Opening and closing of the valve is controlled by a thermostatic spring or vacuum motor. On thermostatic spring type valves, a weight is installed on the valve shaft to minimize valve flutter as the exhaust gas discharges from the cylinders. This system is used to warm the intake manifold for better fuel vaporization during engine warm up.



VACUUM MOTOR TYPE

THERMOSTATIC SPRING TYPE



BASIC GASOLINE ENGINE

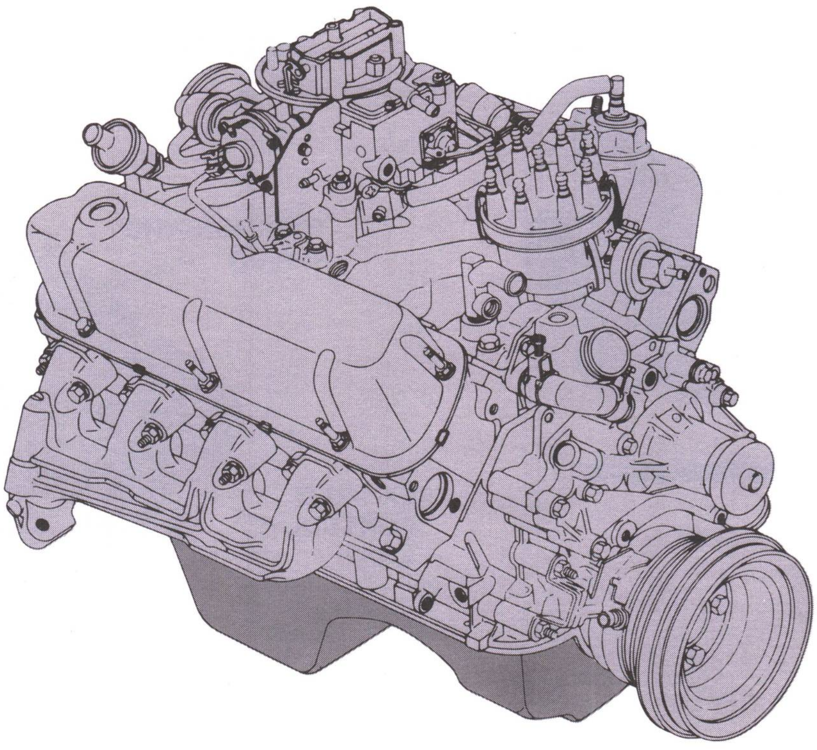
ENGINE CONSTRUCTION

The two most common materials used for engine construction are cast iron and aluminum. Each has its own advantages.

Let's look first at cast iron as this is the oldest continuously used material for automobile engine construction. What is cast iron? Cast iron is a commercial alloy of iron, carbon and silicon that is cast in a mold. Cast iron is hard, brittle, non-malleable and incapable of being hammer-welded. Cast iron is more fusible than steel when molten. Many metals are hard, most are also malleable, which means they can be extended or shaped by beating. Cast iron cannot be extended or shaped. This is very important point when considering engine construction. The engine block and components must resist being extended or stretched from the high pressures and heat contained within it.

Cast iron does have one drawback, it is heavy. This is of little concern when the engine is large and capable of delivering high horsepower. Cast iron engines in today's automobiles are generally large six and eight cylinder models. Also, most high performance engines designed for racing are made of cast iron.

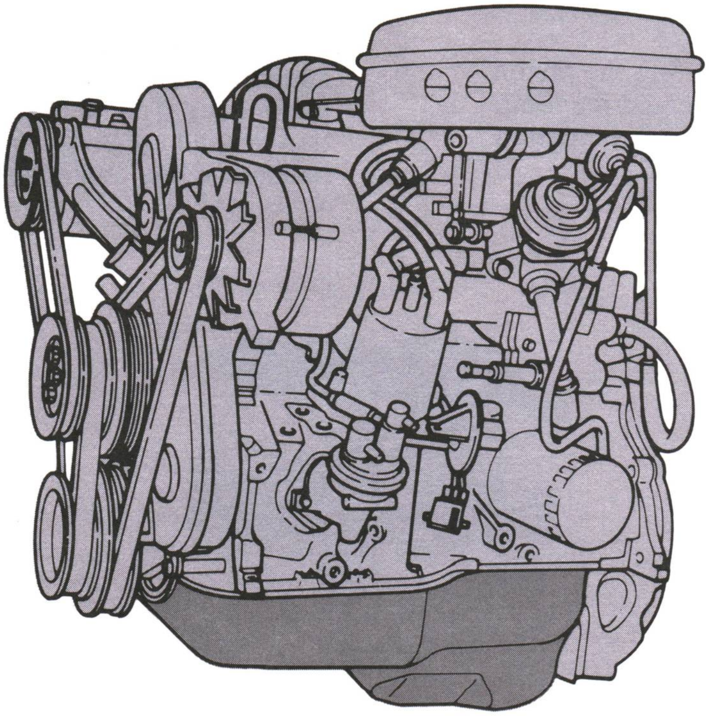
Cast iron is not easily damaged by heat. Engine overheating, unless it is extremely severe, has little effect on a cast iron engine.



TYPICAL V-8 ENGINE

The second material, aluminum, is becoming more popular for engine construction. This is primarily because of its light weight which is an important factor in today's smaller automobiles. First what is aluminum? Aluminum is a bluish silver-white, malleable ductile light metallic element with good electrical and thermal conductivity. It is highly reflective and has good resistance to oxidation. Pure aluminum is not a good material for engine block or head construction. It is too soft and malleable. It would not contain the pressure created by combustion. Cylinder blocks and heads are made of an aluminum alloy. This is aluminum blended with other metals to give it the necessary strength. Aluminum is not resistant to friction wear. For this reason cast iron cylinder liners must be used. Aluminum is also easily damaged by heat so again a need for an alloy.

Today's scientific and engineering practices have overcome the shortcomings of aluminum for use in automobile engines.



TYPICAL 4-CYLINDER ENGINE

GASOLINE ENGINE APPLICATION

AUTOMOTIVE VERSUS INDUSTRIAL USE

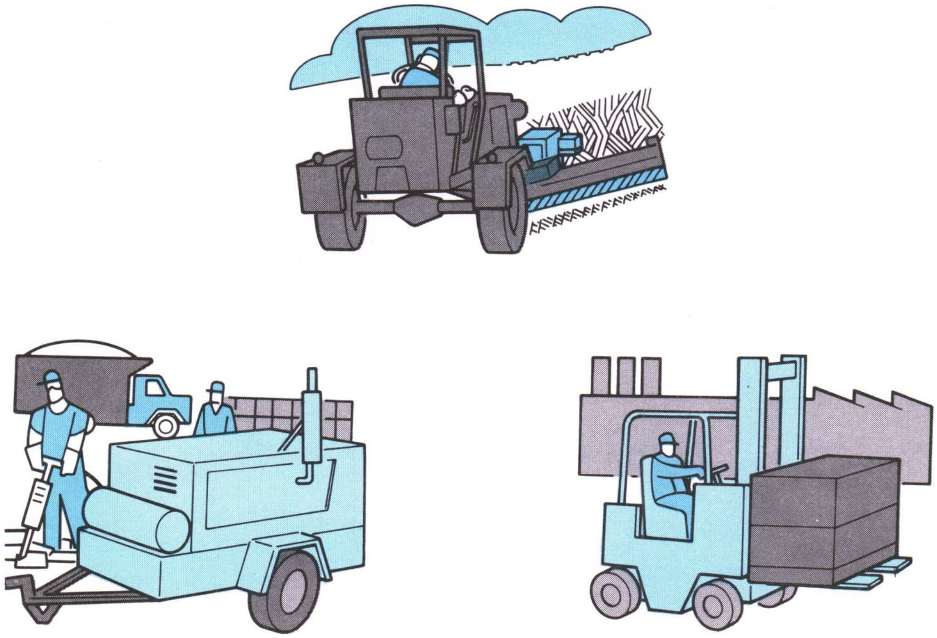
Many Ford engine families are used for both automotive and industrial use. They appear the same on the outside and may even be the same displacement. Normally this is where the similarity ends.

Industrial engines are designed for a special use, such as powering a generator. The engine most often operates in a controlled environment, it will operate at one or two R.P.M. ranges and the load is known. The internal design of the engine can be tailored to its application.

The main areas of difference are the piston design, camshaft design, exhaust manifold design, ignition type and the fuel induction system.

As explained earlier in this manual, there are two basic piston skirt designs, slippered and full skirt. The slipper design is being used primarily in automobile engines. The full skirt pistons are used in truck and industrial engines. These engines generally must withstand heavier loads and will benefit from the larger piston thrust surface. The full skirt pistons are heavier than the slipper type. This has the tendency to cause the engine to accelerate slower, but this is not a problem for industrial use. The piston dome may also have a different design as the engine may require a change in compression ratio.

The camshaft design will be altered as the engine will have to perform better at a given speed, rather than at all speed ranges as in an automobile. The lobe placement, lift and duration may all be altered in order to attain the needed engine characteristics.



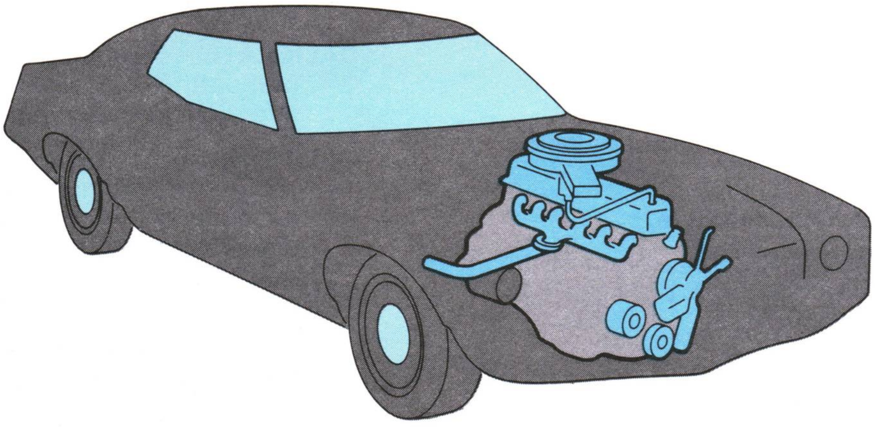
TYPICAL INDUSTRIAL USAGE

The exhaust manifold and exhaust system will be redesigned to fit the space provided. Exhaust noise and emission must be controlled as needed by the user.

The ignition system generally will be the breaker point type. The distributor may contain a vacuum advance and mechanical advance system matched to the use of the engine, however, most industrial engine ignition systems will contain only a mechanical advance system. The engine generally will be working at one or maybe two R.P.M. ranges. A mechanical system will adequately handle the advance necessary.

The fuel delivery system will generally be the carburetor type. The engine will be operated in a controlled environment. It will have to be designed to stand and run well in its environment rather than the extreme changes that are faced by an automobile engine.

To recap, an automobile engine must be designed to start and operate well under all conditions. It must accept varying loads and speeds. It must also operate economically to satisfy today's operator. The industrial engine will perform the same operation in the same environment for its entire life. It must do its job well and last as long as possible. In short, all engines, even engines of the same family, are not created equally.



BASIC GASOLINE ENGINE
GLOSSARY

ADDITIVE: As used with reference to automotive oils, a material added to the oil to give it certain properties. For example, a material added to engine oil to lessen its tendency to congeal or thicken at low temperature.

AIR: A gas containing approximately 4/5 nitrogen, 1/5 oxygen and some carbonic gas.

AIR CLEANER: A device for filtering, cleaning and removing dust from the air admitted to a unit, such as an engine or air compressor.

AIR GAP: The space between spark plug electrodes, motor and generator armatures, field shoes, etc.

AIR LOCK: A bubble of air trapped in a fluid circuit which interferes with normal circulation of the fluid.

ALLOY: A mixture of different metals such as solder which is an alloy consisting of lead and tin.

ALUMINUM: A metal noted for its lightness and often alloyed with small quantities of other metals for automotive use.

ANNEALING: A process of softening metal. For example, the heating and slow cooling of a piece of iron.

ANTI-FREEZE: A material such as alcohol, glycerin, etc., added to water to lower its freezing point.

API: American Petroleum Institute.

ATMOSPHERIC PRESSURE: The weight of the air at sea level; about 14.7 lbs. per square inch; less at higher altitudes.

BACK-PRESSURE: A resistance to free flow, such as a restriction in the exhaust line.

BATTERY: As used with reference to an automobile, any number of complete electrical cells assembled in one housing or case.

B.D.C.: Bottom dead center.

BEARING: A part in which a journal, pivot or the like turns or moves.

B.H.P.: (Brake Horsepower): A measurement of the power developed by an engine in actual operation.

BLOW-BY: A leakage or loss of pressure often used with reference to leakage of compression past the piston ring between the piston and the cylinder.

BOILING POINT: The temperature at atmospheric pressure at which bubbles or vapors rise to the surface and escape.

BORE: The diameter of a hole, such as a cylinder; also to enlarge a hole as distinguished from making a hole with a drill.

BORING BAR: A stiff bar equipped with multiple cutting bits which is used to bore a series of bearings or journals in proper alignment with each other.

BOSS: An extension or strengthened section, such as the projections within a piston which support the piston pin or piston pin bushings.

B.T.U. (British Thermal Unit): A measurement of the amount of heat required to raise the temperature of 1 lb. of water, 1 degree, Fahrenheit.

BURNISH: To smooth or polish by the use of a sliding tool under pressure.

BUSHING: A removable liner for a bearing.

BY-PASS: An alternate path for a flowing substance.

CALIBRATE: To determine or adjust the graduation or scale of any instrument giving quantitative measurements.

CALIPERS (Inside and Outside): An adjustable tool for determining the inside or outside diameter by contact and retaining the dimension for measurement or comparison.

CAM OR BREAKER CAM: The multi-lobed cam rotating in the ignition distributor which interrupts the primary circuit to induce a high tension spark for ignition.

CAM ANGLE: Also known as dwell period. Referring to an ignition distributor, the number of degrees of rotation of the ignition distributor shaft during which the contact points are closed.

CAM GROUND PISTON: A piston ground to a slightly oval shape which under the heat of operation becomes round.

CAMSHAFT: The shaft containing lobes or cams to operate the engine valves.

CAPE CHISEL: A metal cutting chisel shaped to cut or work in channels or grooves.

BASIC GASOLINE ENGINE
GLOSSARY

CARBON: A common non-metallic element which is an excellent conductor of electricity. It also forms in the combustion chamber of an engine during the burning of fuel and lubricating oil.

CARBON DIOXIDE: Compressed into solid form, this material is known as "dry ice" and remains at a temperature of 109°F. It goes directly from a solid to a vapor state.

CARBON MONOXIDE: Gas formed by incomplete combustion. Colorless, odorless, very poisonous.

CARBONIZE: The process of carbon formation within an engine, such as on the spark plugs and within the combustion chamber.

CARBURETOR: A device for automatically mixing fuel in the proper proportion with air to produce a combustible gas.

CASE-HARDEN: To harden the surface of steel.

CENTIGRADE: A measurement of temperature used principally in foreign countries, zero on the Centrigrade scale being 32° on the Fahrenheit scale.

CENTRIFUGAL FORCE: A force which tends to move a body away from its center of rotation. An example is supplied by whirling a weight attached to a string.

CHAMFER: A bevel or taper at the edge of a hole.

CHASE: To straighten up or repair damaged threads.

CHASSIS DYNAMOMETER: A machine for measuring the power delivered to the drive wheels of a vehicle.

CHECK-VALVE: A gate or valve which allows passage of gas or fluid in one direction only.

CHILLED IRON: Cast iron on which the surface has been hardened.

CHROMIUM STEEL: An alloy of steel with a small amount of chromium to produce a metal which is highly resistant to oxidation and corrosion.

CLEARANCE: The space allowed between two parts, such as between a journal and a bearing.

CLOCKWISE ROTATION: Rotation in the same direction as the hands of a clock.

COEFFICIENT OF FRICTION: A measurement of the amount of friction developed between two surfaces pressed together and moved one on the other.

COIL: (In electric circuits) Turns of wire on a core, enclosed in a case, through which electrical current passes.

"COLD" MANIFOLD: An intake manifold to which the exhaust gas is not applied for heating purposes.

COMBUSTION: The process of burning.

COMBUSTION SPACE OR CHAMBER: In automobile engines, the volume of the cylinder above the piston with the piston on top center.

COMPOUND: A mixture of two or more ingredients.

COMPRESSION: The reduction in volume or the "squeezing" of a gas. As applied to metal, such as a coil spring, compression is the opposite of tension.

COMPRESSION RATIO: The volume of the combustion chamber at the end of the compression stroke as compared to the volume of the cylinder and chamber with the piston on bottom center.

COMPRESSION RINGS: The upper rings on a piston designed to hold the compression in the cylinder.

COMPRESSION STROKE: The piston stroke from B.D.C. to T.D.C. during which both valves are closed and the gases in the cylinder are compressed.

CONCENTRIC: Two or more circles, having a common center.

CONDENSATION: The process of a vapor becoming a liquid; the reverse of evaporation.

CONNECTING ROD: Rod that connects the piston to the crankshaft.

CONTRACTION: A reduction in mass or dimension; the opposite of expansion.

CONVECTION: A transfer of heat by circulating heated air.

COOLANT: The liquid that circulates in an engine cooling system.

BASIC GASOLINE ENGINE
GLOSSARY

CORRODE: To eat away gradually as if by gnawing, especially by chemical action, such as rust.

COUNTERBORE: To enlarge a hole to a given depth.

COUNTER-CLOCKWISE ROTATION: Rotating the opposite direction of the hands on a clock. The same as anti-clockwise rotation.

COUNTERSINK: To cut or form a depression to allow the head of a screw to go below the surface.

CRANKCASE: The housing within which the crankshaft and many other parts of the engine operate.

CRANKCASE DILUTION: Under certain conditions of operation, unburned portions of the fuel find their way past the piston rings into the crankcase and oil reservoir where they dilute or "thin" the engine lubricating oil.

CRANKSHAFT: The main shaft of an engine which in conjunction with the connecting rods changes the reciprocating motion of the pistons into rotary motion.

CRANKSHAFT COUNTER-BALANCE: A series of weights attached to or forged integrally with the crankshaft so placed as to offset the reciprocating weight of each piston and rod assembly.

CRUDE OIL: Liquid oil as it comes from the ground.

CU. IN.: Cubic Inch.

CYLINDER: A round hole having some depth bored to receive a piston; also sometimes referred to as "bore" or "barrel."

CYLINDER BLOCK: The largest single part of an engine. The basic or main mass of metal in which the cylinders are bored or placed.

CYLINDER HEAD: A detachable portion of an engine fastened securely to the cylinder block which contains all or a portion of the combustion chamber.

CYLINDER SLEEVE: A liner or tube interposed between the piston and the cylinder wall or cylinder block to provide a readily renewable wearing surface for the cylinder.

DEAD CENTER: The extreme upper or lower position of the crankshaft throw at which the piston is not moving in either direction.

DEGREE: Abbreviated deg. or indicated by a small "0" placed alongside of a figure; maybe used to designate temperature readings or may be used to designate angularity, one degree being 1/360 part of a circle.

DENSITY: Compactness; relative mass of matter in a given volume.

DETERGENT: A compound of a soap-like nature used in engine oil to remove engine deposits and hold them in suspension in the oil.

DETONATION: As used in an automobile, indicates a too rapid burning or explosion of the mixture in the engine cylinders. It becomes audible through a vibration of the combustion chamber walls and is something confused with a "ping" or spark knock.

DIAL GAUGE: A type of micrometer wherein the readings are indicated on a dial rather than on a thimble as in a micrometer.

DIAPHRAGM: A flexible partition or wall separating two cavities.

DIE: One of a pair of hardened metal blocks for forming metal into a desired shape or a thread die for cutting external threads.

DIE CASTING: An accurate and smooth casting made by pouring molten metal or composition into a metal mold or die under pressure.

DISTORTION: A warpage or change in form from the original shape.

DOWEL PIN: A pin inserted in matching holes in two parts to maintain those parts in fixed relation one to the other.

DRAW-FILING: A method of filing wherein the file is drawn across the work while held at a right angle to the length of the file.

DRILL: A tool for making a hole or to sink a hole with a pointed cutting tool rotated under pressure.

DRIVE-FIT: Also known as a force-fit or press-fit. This term is used when the shaft is slightly larger than the hole and must be forced in place.

DROP FORGING: A piece of steel shaped between dies while hot.

DWELL PERIOD: Also known as cam angle.

BASIC GASOLINE ENGINE
GLOSSARY

DYNAMOMETER: A machine for measuring the actual power produced by an internal combustion engine.

ECCENTRIC: One circle within another circle wherein both circles do not have the same center. An example of this is a cam on a camshaft.

ENGINE: As used in automobiles, the term applies to the prime source of power generation used to propel the vehicle.

ENGINE DISPLACEMENT: The sum of the displacement of all the engine cylinders. See Piston Displacement.

EXHAUST MANIFOLD: That part of an engine through which exhausted or spent gases flow to the exhaust system.

EXHAUST PIPE: The pipe connecting the engine to the muffler to conduct the exhausted or spent gases away from the engine.

EXHAUST VALVE: A valve that permits the exhausted or spent gases to escape from a chamber.

EXPANSION: An increase in size. For example, when a metal rod is heated it increases in length and perhaps also in diameter; expansion is the opposite of contraction.

FAHRENHEIT (F.): A scale of temperature measurement ordinarily used in English speaking countries. The boiling point of water is 212 degrees, Fahrenheit, as compared to 100 degrees Centigrade.

FEELER GAUGE: A metal strip or blade finished accurately with regard to thickness used for measuring the clearance between two parts; such gauges ordinarily come in a set of different blades graduated in thickness by increments of .001 in.

FERROUS METAL: Metals which contain iron or steel and are therefore subject to rust.

FILE: To finish or trim with a hardened rasp or file.

FILLET: A rounded filling between two parts joined at an angle.

FILTER (Oil, Water, Gasoline, Etc.): A unit containing an element, such as a screen of varying degrees of fineness. The screen or filtering element is made of various materials depending upon the size of the foreign particles to be eliminated from the fluid being filtered.

FIT: A kind of contact between two machined surfaces.

FLANGE: A projecting rim or collar on an object for keeping it in place.

FLOATING PISTON PIN: A piston pin which is not locked in the connecting rod or the piston, but is free to turn or oscillate in both the connecting rod and the piston.

"FLUTTER" OR "BOUNCE": As applied to engine valves, refers to a condition wherein the valve is not held tightly on its seat during the time the cam is not lifting it.

FLYWHEEL: A heavy wheel in which energy is absorbed and stored by means of momentum.

FOOT POUND (or lbs. ft.): This is a measure of the amount of energy or work required to lift 1 lb. to 1 ft.

FORCE-FIT: Also known as a press-fit or drive-fit. This term is used when the shaft is slightly larger than the hole and must be forced in place.

FORGE: To shape metal while hot and plastic by hammering.

FOUR CYCLE ENGINE: Also known as Otto cycle, wherein an explosion occurs every other revolution of the crankshaft; a cycle being considered as 1/2 revolution of the crankshaft. These strokes are (1) intake stroke; (2) compression stroke; (3) power stroke; (4) exhaust stroke.

FREE-WHEELING: A mechanical device which will engage the driving member to impart motion to a driven member in one direction but not the other. Also known as an overrunning clutch.

FUEL KNOCK: Same as detonation.

FULCRUM: The support on which a lever turns in moving a body.

GASKET: Anything used as a packing, such as a non-metallic substance placed between two metal surfaces to act as a seal.

GLAZE: As used to describe the surface of the cylinder, an extremely smooth or glossy surface such as a cylinder wall highly polished over a long period of time by the friction of the piston rings.

BASIC GASOLINE ENGINE
GLOSSARY

GLAZE BREAKER: A tool for removing the glossy surface finish in an engine cylinder.

GRIND: To finish or polish a surface by means of an abrasive wheel.

GUDGEON PIN: Also known as "wrist pin" and piston pin. This is the pin that connects the connecting rod to the piston and piston pin is the preferred term.

GUM: In automotive fuels, this refers to oxidized petroleum products which accumulate in the fuel system, carburetor or engine parts.

HARMONIC BALANCER: A device to reduce the torsional or twisting vibration which occurs along the length of the crankshaft used in multiple cylinder engines. Also known as a vibration damper.

H.C.: High compression.

HEAT RISER: The passage in the manifold between the exhaust and intake manifold.

HEAT TREATMENT: A combination of heating and cooling operations timed and applied to a metal in a solid state in a way that will produce desired properties.

HELICAL: Shaped like a coil of wire or a screw thread.

HONE: An abrasive tool for correcting small irregularities or differences in diameter in a cylinder, such as an engine cylinder or a brake cylinder.

HOT SPOT: Refers to a comparatively thin section or area of the wall between the inlet and exhaust manifold of an engine, the purpose being to allow the hot exhaust gases to heat the comparatively cool incoming mixture. Also used to designate local areas of the cooling system which have attained above average temperatures.

HP: Horsepower, the energy required to lift 550 lbs. 1 ft. in 1 second.

HYDROCARBON: Any compound composed entirely of carbon and hydrogen, such as petroleum products.

HYDROCARBON ENGINE: An engine using petroleum products, such as gas, liquefied gas, gasoline, kerosene or fuel oil as a fuel.

I.D.: Inside Diameter.

IDLE: Refers to the engine operating at its slowest speed with a vehicle not in motion.

IGNITION DISTRIBUTOR: An electrical unit that provides a means for conveying the secondary or high tension current to the spark plug wires as required.

IGNITION SYSTEM: The means for igniting the fuel in the cylinders.

I.H.P.: Indicated horsepower developed by an engine and a measurement of the pressure of the explosion within the cylinder expressed in pounds per square inch.

IN.: Inch.

INERTIA: A physical law which tends to keep a motionless body at rest or also tends to keep a moving body in motion; effort is thus required to start a mass moving or to retard or stop it once it is in motion.

INHIBITOR: A material to restrain or hinder some unwanted action, such as a rust inhibitor which is a chemical added to cooling systems to retard the formation of rust.

INLET VALVE OR INTAKE VALVE: A valve which permits a fluid or gas to enter a chamber and sels against exit.

INTAKE MANIFOLD OR INLET PIPE: The tube used to conduct the gasoline and air mixture from the carburetor to the engine cylinders.

JOURNAL: A bearing within which a shaft operates.

KEY: A small block inserted between the shaft and hub to prevent circumferential movement.

KEYWAY OR KEYSEAT: A groove or slot cut to permit the insertion of a key.

KNURL: To indent or roughen a finished surface.

KNOCK: A general term used to describe various noises occurring in an engine; may be used to describe noises made by loose or worn mechanical parts, pre-ignition, detonation, etc.

LAPPING: The process of fitting one surface to another by rubbing them together with an abrasive material between the two surfaces.

LB.: Pound.

L.C.: Low compression.

BASIC GASOLINE ENGINE
GLOSSARY

LINER: Usually a thin section placed between two parts, such as a replaceable cylinder liner in an engine.

LITER: A metric measure equal to 2.11 pints.

MALLEABLE CASTING: A casting which has been toughened by annealing.

MANIFOLD: A pipe with multiple openings used to connect various cylinders to one inlet or outlet.

MANGANESE BRONZE: An alloy of copper, zinc and manganese.

MECHANICAL EFFICIENCY (Engine): The ratio between the indicated horsepower and the brake horsepower of an engine.

MICROMETER: A measuring instrument for either external or internal measurement in thousandths and sometimes tenths of thousandths of inches.

MILL: To cut or machine with rotating tooth cutters.

MILLIMETER (mm): One millimeter is the metric equivalent of .039370 of an inch or one inch being the equivalent of 25.4 mm.

MISFIRING: Failure of an explosion to occur in one or more cylinders while the engine is running; may be continuous or intermittent failure.

MOTOR: Actually this term should be used in connection with an electric motor and should not generally be used when referring to the engine of an automobile.

M.P.H.: Miles per hour.

MUFFLER: A chamber attached to the end of the exhaust pipe which allows the exhaust gases to expand and cool. It is usually fitted with baffles or porous plates and serves to subdue much of the noise created by the exhaust.

NEEDLE BEARING: An anti-friction bearing using a great number of small diameter rollers of greater length.

NON-FERROUS METALS: This designation includes practically all metals which contain no iron or very little iron and are therefore not subject to rusting.

OCTANE NUMBER: A unit of measurement on a scale intended to indicate the tendency of a fuel to detonate or knock.

OCTANE SELECTOR: A calibrated device for adjusting the timing of the ignition distributor in accordance with the characteristics of the fuel in use.

O.D.: Outside diameter.

OIL PUMPING: A term used to describe an engine which is using an excessive amount of lubricating oil.

OSCILLATE: To swing back and forth like a pendulum.

OTTO CYCLE: Also called four stroke cycle. Named after the man who adopted the principle of four cycles of operation for each explosion in an engine cylinder. They are (1) intake stroke, (2) compression stroke, (3) power stroke, (4) exhaust stroke.

OVERHEAD VALVE OR VALVE-IN-HEAD ENGINE: An engine design having valves located in the cylinder head directly above the pistons.

PEEN: To stretch or clinch over by pounding with the rounded end of a hammer.

PETCOCK: A small valve placed at various points in a fluid circuit usually for draining purposes.

PETROLEUM: A group of liquid and gaseous compounds composed of carbon and hydrogen which are removed from the earth.

PHOSPHOR-BRONZE: An alloy consisting of copper, tin and lead sometimes used in heavy duty bearings.

PISTON: A cylindrical part closed at one end which is connected to the crankshaft by the connecting rod. The force of the explosion in the cylinder is exerted against the closed end of the piston causing the connecting rod to move the crankshaft.

PISTON COLLAPSE: A condition describing a collapse or a reduction in diameter of the piston skirt due to heat or stress.

PISTON DISPLACEMENT: The volume of air moved or displaced by moving the piston from one end of its stroke to the other.

PISTON HEAD: That part of the piston above the rings.

PISTON LANDS: Those parts of a piston between the piston rings.

GLOSSARY

PISTON PIN: The journal for the bearing in the small end of an engine connecting rod which also passes through piston walls; also known as a wrist pin.

PISTON RING: An expanding ring placed in the grooves of the piston to provide a seal to prevent the passage of fluid or gas past the piston.

PISTON RING EXPANDER: A spring placed behind the piston ring in the groove to increase the pressure of the ring against the cylinder wall.

PISTON RING GAP: The clearance between the ends of the piston ring.

PISTON RING GROOVE: The channel or slots in the piston in which the piston rings are placed.

PISTON SKIRT: That part of the piston below the rings.

PISTON SKIRT EXPANDER: A spring or other device inserted in the piston skirt to compensate for collapse or decrease in diameter.

POPPET VALVE: A valve structure consisting of a circular head with an elongated stem attached in the center which is designed to open and close a circular hole or port.

PORT: In engines, the openings in the cylinder block for valves, exhaust and inlet pipes, or water connections. In two-cycle engines the openings for inlet and exhaust purposes.

"PORTING": As generally applied to racing engines, the enlarging, matching, streamlining and polishing of the inside of the manifolds and valve ports to reduce the friction of the flow of gases.

PRE-HEATING: The application of heat as a preliminary step to some further thermal or mechanical treatment.

PRE-IGNITION: Ignition occuring earlier than intended. For example, the explosive mixture being fired in a cylinder as by a flake of incandescent carbon before the electric spark occurs.

PRESS-FIT: Also known as a force-fit or drive-fit. This term is used when the shaft is slightly larger than the hole and must be forced in place.

PRIMARY WIRES: The wiring circuit used for conducting the low tension or primary current to the points where it is to be used.

P.S.I.: A measurement of pressure in pounds per square inch.

PUSH ROD: A connecting link in an operating mechanism, such as the rod interposed between the valve lifter and rocker arm on an overhead valve engine.

QUENCHING: A process of rapid cooling of hot metal by contact with liquid, gases or solids.

RACE: As used with reference to bearings, a finished inner and outer surface in which or on which balls or rollers operate.

"RACE-CAM": A type of camshaft for race cars which increases the lift of the valve, increases the speed of valve opening and closing, increases the length of time the valve is held open, etc. Also known as "Full," "Three-quarter" or "Semi-race cams," depending upon design.

RADIATION: The transfer of heat by rays, such as heat from the sun.

RATIO: The relation or proportion that one number bears to another.

REAM: To finish a hole accurately with a rotating fluted tool.

RECIPROCATING: A back and forth movement, such as the action of a piston in a cylinder.

RELIEF: The amount one surface is set below or above another surface.

"RELIEVING": As applied to racing engines, the removal of some metal from around the valves and between the cylinder and valves to facilitate flow of the gases.

RESISTOR: A current consuming piece of metal wire or carbon inserted into an electrical circuit to decrease the flow.

RETARD: When used with reference to an ignition distributor, means to cause the spark to occur at a later time in the cycle of engine operation; opposite of spark advance.

ROCKER ARM: In an automobile engine a lever located on a fulcrum or shaft, one end of the lever being on the valve stem; the other being on the push rod.

ROCKWELL HARNESS: A scale for designating the degree of hardness possessed by a substance.

ROLLER BEARING: An inner and outer race upon which hardened steel rollers operate.

ROTARY ENGINE: An engine construction wherein the crankshaft remains stationary and the cylinders spin around it as in a pin wheel.

ROTARY VALVE: A valve construction in which ported holes come into and out of register with each other to allow entrance and exit of fluids or gases.

R.P.M.: Revolutions per minute.

RUBBER: An elastic vibration absorbing material of either natural or synthetic origin.

RUNNING-FIT: Where sufficient clearance has been allowed between the shaft and journal to allow free running without overheating.

SAE: Society of Automotive Engineers.

SAE STEELS: A numerical index system used to identify composition of SAE steel. Basically the first digit indicating the type to which the steel belongs; thus (1) indicates a carbon steel, (2) a nickel steel, etc. The second digit generally indicates the approximate percentage of the predominant alloying element. Usually the last two or three digits indicates the approximate average carbon content in points or hundredths of 1 per cent. Thus (SAE 2340 steel) indicates a nickel steel of approximately 3 per cent nickel and 0.40 per cent carbon.

SAE THREAD: Refers to a table of threads set up by the society of Automotive Engineers and determines the number of threads per inch. For example, a quarter inch diameter rod with an SAE thread would have 28 threads per inch.

SAFETY RELIEF VALVE: A spring loaded valve designed to open and thus relieve excessive pressure in a vessel when it exceeds a predetermined safe point.

SAND BLAST: To clean a surface by means of sand propelled by compressed air.

SAYBOLT TEST: A method of measuring the viscosity of oil with the use of a viscosimeter.

SCALE: A flaky deposit occuring on steel or iron. Ordinarily used to describe the accumulation of minerals and metals accumulating in an automobile cooling system.

SCORE: A scratch, ridge or groove marring a finished surface.

SEAT: A surface, usually machined, upon which another part rests or seats; for example, the surface upon which a valve face rests.

SEIZE: When one surface moving upon another scratches, it is said to seize. An example is a piston score or abrasion in a cylinder due to lack of lubrication or over-expansion.

SHRINK-FIT: Where the shaft or part is slightly larger than the hole in which it is to be inserted. The outer part is heated above its normal operating temperature or the inner part chilled below its normal operating temperature or both and assembled in this condition; upon cooling an exceptionally tight fit is obtained.

SILVER SOLDERING: Same as Hard Soldering.

SLEEVE VALVE: A reciprocating sleeve or sleeves with ported openings placed between the piston and cylinders of an engine to serve as valves.

SLIDING-FIT: Where sufficient clearance has been allowed between the shaft and journal to allow free running without overheating.

SLIP-IN BEARING: A liner made to extremely accurate measurements which can be used for replacement purposes without additional fitting.

SLUDGE: As used in connection with automobile engines, indicates a composition of oxidized petroleum products along with an emulsion formed by the mixture of oil and water. This forms a pasty substance and clogs oil lines and passages and interferes with engine lubrication.

SOLDER: An alloy of lead and tin used to unite two metal parts.

SOLDERING: To unite two pieces of metal with a material, such as solder having a comparatively low melting point.

SOLVENT: A solution which dissolves some other material. For example, water is a solvent for sugar.

SPARK: An electrical current possessing sufficient pressure to jump through the air from one conductor to another.

SPARK ADVANCE: When used with reference to an ignition distributor, means to cause the spark to occur at an earlier time in the cycle of engine operation; opposite of retard.

SPARK GAP: The space between the electrodes of a spark plug through which the spark jumps. Also a safety device in a magneto to provide an alternate path for the current when it exceeds a safe value.

SPARK KNOCK: Same as Pre-ignition.

SPARK PLUG: A device inserted into the combustion chamber of an engine containing an insulated central electrode for conducting the high tension current from the ignition distributor or magneto. This insulated electrode is spaced a pre-determined distance from the shell or side electrode in order to control the dimensions of the gap for the spark to jump across.

SQ. FT.: Square feet.

SQ. IN.: Square inch.

STAMPING: A piece of sheet metal cut and formed into the desired shape with the use of dies.

STANDARD THREAD: Refers to the U.S.S. table of the number of threads per inch. For example, a quarter inch diameter standard thread would have 20 threads per inch.

STEEL CASTING: Cast iron to which varying amounts of scrap steel have been added.

STELLITE: An alloy of cobalt, chrome and tungsten which is often used for exhaust valve seat inserts. It has a high melting point, good corrosion resistance and unusual hardness when hot.

STRESS: The force or strain to which a material is subjected.

STROKE: In an automobile engine, the distance moved by the piston.

"STROKING": As applied to racing engines, remachining the crankshaft throws off center to alter the stroke.

STUDS: A rod with threads cut on both ends, such as a cylinder stud which screws into the cylinder block on one end and has a nut placed on the other end to hold the cylinder head in place.

SUCTION: Suction exists in a vessel when the pressure is lower than the atmospheric pressure; also see Vacuum.

TACHOMETER: A device for measuring and indicating the rotative speed of an engine.

TAP: To cut threads in a hole with a tapered, fluted, threaded tool. In England, term for drain cock.

TAPPET: The adjusting screw for varying the clearance between the valve stem and the cam. May be built into the valve lifter in an engine or may be installed in the rocker arm on an overhead valve engine.

T.D.C.: Top dead center.

THERMO EFFICIENCY: A gallon of fuel contains a certain amount of potential energy in the form of heat when burned in the combustion chamber. Some of this heat is lost and some is converted into power. The thermal efficiency is the ratio of work accomplished compared to the total quantity of heat contained in the fuel.

THERMOSTAT: A heat controlled valve used in the cooling system of an automobile engine to regulate the flow of water between the cylinder block and the radiator or used in the electrical circuit of the car heating system to control the amount of heat supplied to the passengers.

THROW: With reference to an automobile engine, usually the distance from the center of the crankshaft main bearing to the center of the connecting rod journal.

TIMING CHAIN: Chain used to drive camshaft and accessory shafts of an engine.

TIMING GEARS: Any group of gears which are driven from the engine crankshaft to cause the valves, ignition and other engine driven apparatus to operate at the desired time during the engine cycle.

TOLERANCE: A permissible variation between the two extremes of a specification of dimensions.

TORQUE: An effort devoted toward twisting or turning.

GLOSSARY

TORQUE WRENCH: A special wrench with a built-in indicator to measure the applied force.

TURBULENCE: A disturbed or disordered, irregular motion of fluids or gases.

UPPER CYLINDER LUBRICATION: A method of introducing a lubricant into the fuel or intake manifold in order to permit lubrication of the upper cylinder, valve guides, etc.

VACUUM: The term ordinarily used to describe a lack of pressure or a partial vacuum, that is, a pressure less than atmospheric pressure.

VACUUM CONTROL: In an ignition distributor, a diaphragm attached to the spark advance which is controlled by the changing of vacuum in the intake manifold.

VACUUM GAUGE: An instrument designed to measure the degree of vacuum existing in a chamber.

VALVE: A valve is a device for opening and sealing an aperture.

VALVE CLEARANCE: The air gap allowed between the end of the valve stem and the valve lifter or rocker arm to compensate for expansion due to heat.

VALVE FACE: That part of a valve which mates with and rests upon a seating surface.

VALVE GRINDING: Also called valve lapping. A process of lapping or mating the valve seat and valve face usually performed with the aid of an abrasive.

VALVE HEAD: The portion of the valve upon which the valve face is machined.

VALVE-IN-HEAD ENGINE: Same as overhead valve engine.

VALVE KEY OR VALVE LOCK: The key, washer, or other device which holds the valve spring cup or washer in place on the valve stem.

VALVE LIFTER: A push rod or plunger placed between the cam and the valve on an engine; is often adjustable to vary the length of the unit.

VALVE MARGIN: On a poppet valve the space or rim between the surface of the head and the surface of the valve face.

VALVE OVERLAP: An interval expressed in degrees where both valves of an automobile engine cylinder are open at the same time.

VALVE SEAT: The matched surface upon which the valve face rests.

VALVE SPRING: A spring attached to a valve to return it to the seat after it has been released from the lifting or opening means.

VALVE STEM: That portion of a valve which rests within a guide.

VALVE STEM GUIDE: A bushing or hole in which the valve stem is placed which allows lateral motion only.

VAPOR LOCK: A condition wherein the fuel boils in the fuel system forming bubbles which retard or stop the flow of fuel to the carburetor.

VIBRATION DAMPER: A device to reduce the torsional or twisting vibration which occurs along the length of the crankshaft used in multiple cylinder engines; also known as a harmonic balancer.

VISCOSIMETER: An instrument for determining the viscosity of an oil by passing a certain quantity at a definite temperature through a standard size orifice or port. The time required for the oil to pass through expressed in seconds gives the viscosity.

VISCOSITY: The resistance to flow or adhesiveness characteristics of an oil.

VOLATILITY: The tendency for a fluid to evaporate rapidly or pass off in the form of vapor. For example, gasoline is more volatile than kerosene as it evaporates at a lower temperature.

VOLUME: The measure of space expressed as cubic inches, cubic feet, etc.

VOLUMETRIC EFFICIENCY: A combination between the ideal and actual efficiency of an internal combustion engine. If the engine completely filled each cylinder on each induction stroke the volumetric efficiency of the engine would be 100 per cent. In actual operation, however, volumetric efficiency is lowered by the inertia of the gases, the friction between the gases and the manifolds, the temperature of the gases and the pressure of the air entering the carburetor. Volumetric efficiency is ordinarily increased by the use of large valves, ports and manifolds and can be further increased with the aid of a supercharger.

VORTEX: A whirling movement or mass of liquid or air.

WHITE METAL: An alloy of tin, lead and antimony having a low melting point and a low coefficient of friction.

WRINGING-FIT: Wherein the clearance is less than for a running or sliding fit and the shaft will enter the hole by means of twisting and pushing by hand.

WRIST PIN: The journal for the bearing in the small end of an engine connecting rod which also passes through piston walls; also known as a piston pin.

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September, 1989 Litho in U.S.A. Order No. 2101-121-STST